Sixth Anniversary

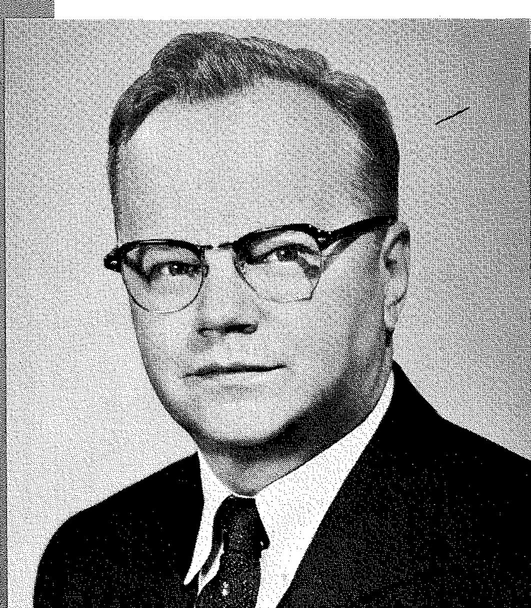
With this issue, the RCA ENGINEER completes its sixth year of publication. In celebrating the occasion, it is appropriate to recall a statement that I wrote in a foreword to the first anniversary issue:

"As we continue to grow we naturally acquire larger engineering groups. It is very important, however, that the identity of the individual is preserved; it is paramount that each member of our staff be fully aware that he or she is an important element in our business. At the same time every engineer must be kept informed."

Through these first six years, the RCA ENGINEER has done a fine job as a vehicle of information *by and for the RCA engineer*. Yet, during these years, the challenge has remained constant as a result of continued growth in our engineering staff. With greater numbers, we are faced persistently with the basic problems of preserving individual identity and of maintaining awareness of the close relationship between engineering and management functions. Thus, the RCA ENGINEER has a continuing opportunity and obligation.

The electronic art to which we are dedicated has experienced a revolution in recent years with the maturing of solid-state physics. The effects have been of immense importance—but these represent only a beginning. Looking to the future, it is probably risky to pinpoint an area in which we might expect an equivalent advance in techniques and tools for progress; however, I would venture to predict that such an area might be that of power-transformation devices—thermoelectric, thermionic, magnetohydrodynamics, fuel cells, the direct conversion of radiant energy—to name the current potentials.

I shall be especially interested in looking back over the pages of the RCA ENGINEER at its tenth and fifteenth anniversaries, to read of RCA's contributions to the continuing advance of electronic technology. And I shall look as well to the RCA ENGINEER for evidence of the growing stature of the engineer and his place in RCA.



E. W. Engstrom

Dr. Elmer W. Engstro
Senior Executive Vice Preside
Radio Corporation of Ameri

CONTENTS

VOL. 7, NO. 1 • JUNE-JULY 1961

RCA ENGINEER

RCA ENGINEER *Staff*

W. O. Hadlock, Editor
E. R. Jennings, Assistant Editor
Miss C. N. Serafino, Editorial Secretary
J. L. Parvin, Art and Production
J. O. Gaynor, Photography

Engineering Editors

K. A. Chittick, Mgr., Engineering Administration, RCA Victor Home Instruments
S. F. Dierk, Technical Publications Administrator, Industrial Electronic Products
C. A. Meyer, Mgr., Commercial Engineering Technical Services, Electron Tube Division
L. A. Thomas, Mgr., Technical Services, Astro-Electronics Division, Defense Electronic Products
F. D. Whitmore, Technical Publications Administrator, Defense Electronic Products

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

ONE OF THE main problems during the preliminary stages of a system study is selection of the optimum design from a number of possible approaches, each having somewhat different performance and costs. The value of a complex system for a given application depends upon the relative importance of many criteria—all of which must be considered, with the right weights given to each. In evaluating competing systems against such a large number of variables, qualitative thinking alone is often inadequate. The exercise of quantitatively determining relative system values, or *worth*, promotes better engineering judgment by illuminating otherwise-unrecognized subjective influences on system thinking and by focusing on the interplay of variables.

Such an analytical means for assessing the worth of

The Engineer and the Corporation

Selecting the Optimum System Approach ...THE WORTH CONCEPT

D. J. BLATTNER
RCA Laboratories, Princeton, N. J.
and
R. G. SHUSTER
Surface Communications Division
DEP, New York, N. Y.

alternate systems is present here: a computable, numeric yardstick that can include all the measurable factors on which selection must be based. This approach also illustrates the variation in worth of a particular system as the weights attached to different factors are varied.

SYSTEMS DEFINITION OF WORTH

Worth is defined as the sum of all the measurable performance factors, including cost, that apply to the system —each factor normalized and weighted in accordance with its importance to the particular application. Identifying, evaluating, and mathematically relating these factors are necessary steps for *objective* system evaluation. A careful statement of system requirements indicates the relative importance of particular performance factors. These factors can be normalized, using appropriate functions to provide performance parameters. The sum of the weighted products of the pertinent normalized parameters is, then, the numerical value of the worth of the system.

An equation for computing worth can be written:

$$W = p_1X_1 + p_2X_2 + \ldots + p_nX_n$$

Where: W = worth, p_i = normalized performance parameter, and X_i = weighting factor. The normalized performance parameter p_i will be obtained from a function:

$$p_i = f(P_i), 0 \leq p_i \leq 1$$

Where: P_i = performance measure of the *i*th performance factor. For example, the performance measure of reliability may be in units of mean-time-between-failure (MTBF).

Weighting factors, X_i, are assigned to each p_i to establish the relative importance of each performance parameter in the particular application. The weighting factors are constrained so that:

$$\sum_{i=1}^{n} X_i = 1$$

Typical performance measures of interest in a particular problem might include size, capacity, procurement cost, MTBF, and maintenance cost. Ideally, a thorough system specification is set up by the system designer or user, by 1) specifying pertinent performance factors, 2) defining the functions $f(P_i)$, and 3) assigning weighting factors to establish relative importance of the performance factors.

APPLICATION TO A COMMUNICATIONS SYSTEM

This simple example will assume only three performance factors important: cost, data rate, and reliability.

Consider a requirement for a communication system between two fixed points. A wire link is desired with a nominal 10-kilobits/sec data-rate capability; reliability equivalent to a 2000-hour MTBF is desired. It is estimated that an information rate below 7.5 kilobits/sec, or an MTBF below 1000 hours will not be acceptable. Information rate or MTBF values greater than twice the desired nominal values are of diminished value in this application and are not to be increasingly favorably weighted. The maximum acceptable cost is considered to be \$5 million. With respect to weightings, cost is regarded of prime importance, closely followed by data rate; reliability is of lesser importance.

Performance Normalization Functions

First, performance normalization functions are established from which the normalized performance parameters can be obtained. A set of graphs (Figures 1, 2, and 3) are used to define the functions. In Fig. 1, the cost normalization function selected is straight-line, such that a zero-cost system has a cost performance parameter of 1.0 (ideal), and a \$5 million system has a zero parameter (unacceptable). Thus, for example, a \$1 million system has twice a cost performance of a \$3 million one ($p = 0.8$ vs. 0.4).

The data-rate normalization function selected (Fig. 2) specifies a value of $p = 0.5$ for the nominally desired data rate of 10 kilobits/sec. Systems having lesser data rates are penalized down to a cutoff value of $p = 0$ at 7.5 kilobits/sec. Systems exceeding the nominal data rate requirement are rewarded, at a lesser rate, to an upper cutoff value of $p = 1.0$ at 20 kilobits/sec. In similar fashion, the reliability normalization function is established about a $p = 0.5$ value at the nominal 2000-hour MTBF value.

Weighting factors of 0.5 for cost, 0.4 for data rate, and 0.1 for reliability are selected to solidify the approximate weightings in the statement of the system requirement.

The rationale behind the illustrated normalization functions and the choice of weighting factors may appear somewhat arbitrary in such a simplified example. Establishment of the form and value of these functions is the *very essence* of a well-defined statement of a system requirement. Careful study and skilled judgment are of course required to make wise choices. Normalization functions are not limited to straight-line segments as in the illustrative example. Any normalization function that, in the judgment of the system engineer, appropriately assigns rewards and penalties for system performance deviations from the nominal range desired in a given application may be used.

Evaluating Two Alternative Approaches

Consider two proposed systems which are to be evaluated against the illustrative system requirement. The first will cost \$4.5 million, with a 12-kilobit/sec data rate and an

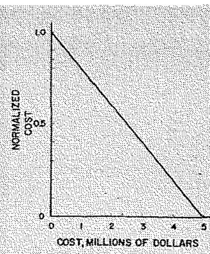


Fig. 1—Normalized cost.

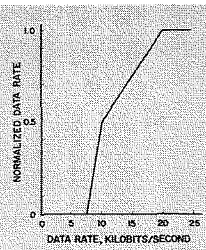


Fig. 2—Normalized data rate.

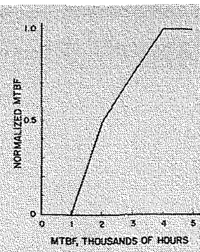


Fig. 3—Normalized reliability.

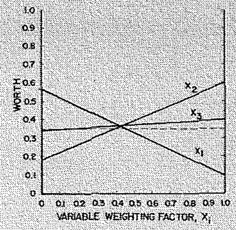


Fig. 4—Worth vs. weighting, first system.

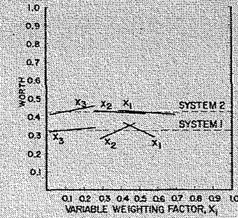


Fig. 5—Worth vs. weighting, both systems.

estimated 1800-hour MTBF. The second will cost $3 million, with a 9.5 kilobit/sec data rate and an estimated 2400-hour MTBF.

Using Figs. 1, 2, and 3, the normalized parameters can be determined for each system. With these parameter values and the weighting functions, the worths of both systems can be computed using the worth equation (Table I). System 2 has the greatest worth in the example chosen. That is, the lower-cost, lower-performance system is judged a better buy for this application on the basis of the normalization functions and weighting chosen.

Sensitivity of Worth to Variation in Weighting Factors

It is often an easier task to establish desired nominal values and appropriate normalization functions for performance measures of interest than it is to select appropriate weighting factors. For this reason, it is of interest to study the sensitivity of system worth to variations in choice of weighting factors.

The approach will be to examine the worth equation for a given system, assuming the performance parameters and an initial set of weighting factors are given. The effects on worth of varying each weighting factor in turn, while holding all the others in their original proportions, can then be determined. For example, the variation in worth with weighting of the cost performance parameter for the first system in the illustrative example can be studied by varying X_1 in the following formulation of the worth equation:

$$W = p_1 X_1 + p_2\left[\bar{X}_2 + \frac{\bar{X}_2(\bar{X}_1 - X_1)}{\bar{X}_2 + \bar{X}_3}\right] + p_{13}\left[\bar{X}_3 + \frac{\bar{X}_3(\bar{X}_1 - X_1)}{\bar{X}_2 + \bar{X}_3}\right]$$

Where: $\bar{X}_1$, $\bar{X}_2$, $\bar{X}_3$ = initial values of cost, data rate, and reliability weighting factors, respectively; p_1, p_2, p_3 = cost, data rate, and reliability performance parameters, respectively; and X_1 = weighting factor being varied (cost weighting). (Note: If X_1 is set equal to $\bar{X}_1$, the worth equation assumes its normal form.)

Similarly the variation of worth with variation in weighting of normalized data rate is given by:

$$W = p_1\left[\bar{X}_1 + \frac{\bar{X}_1(\bar{X}_2 - X_2)}{\bar{X}_1 + \bar{X}_3}\right] + p_2 X_2 + p_3\left[\bar{X}_3 + \frac{\bar{X}_3(\bar{X}_2 - X_2)}{\bar{X}_1 + \bar{X}_3}\right]$$

Where, X_2 = weighting factor being varied (data-rate weighting). The effects of variation in reliability weighting can be determined using a similar equation.

These equations can be plotted with worth as the ordinate and the weighting factor in question as the abscissa. In Fig. 4, three curves have been plotted on such axes for the first system in the illustrative example. The first curve, labeled X_1, shows the variation in worth of the system as weighting of the cost parameter is varied between 0 and 1.0 (data-rate and reliability weightings kept in their original 4-to-1 ratio). The X_2 and X_3 curves show in similar fashion the worth variations with data rate and reliability.

Table I — Sample Evaluation of Worth

		System 1		System 2	
Item	X_i	p_i	Product	p_i	Product
Cost	0.5	0.1	0.05	0.4	0.20
Data Rate	0.4	0.6	0.24	0.4	0.16
Reliability	0.1	0.4	0.04	0.6	0.06
Worth			0.33		0.42

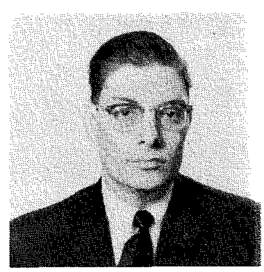
A horizontal line has been drawn across the graph at an ordinate value of 0.33 corresponding to the worth of the system for the original values of weighting factor; i.e. 0.5 cost, 0.4 data rate, and 0.1 reliability. The intersection of this "original" worth line with the weighting-factor-variation curves specifies in each case the nominal value originally given to each weighting factor. By moving along each weighting factor curve away from this intersection point, the variation from the original value of worth due to varying that weighting factor can be determined.

In Fig. 5, the "original" worth lines and weighting-factor-variation curves for both systems used as examples have been superimposed. Only those portions of the weighting factor curves close to the worth lines have been plotted. From this composite curve, it is easy to determine what variation in each weighting factor is required for the worth of the two systems to be equal or interchange.

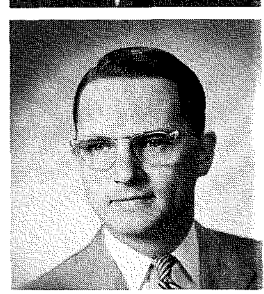
Fig. 5 indicates that the worth of system 2 is relatively insensitive to variation in weighting factors. System 1 increases in worth at a moderate rate with increase in performance weighting or decrease in cost weighting. It is clear, however, that system 2 will maintain its favored rating over a wide range of variation in the original weightings.

SUMMARY

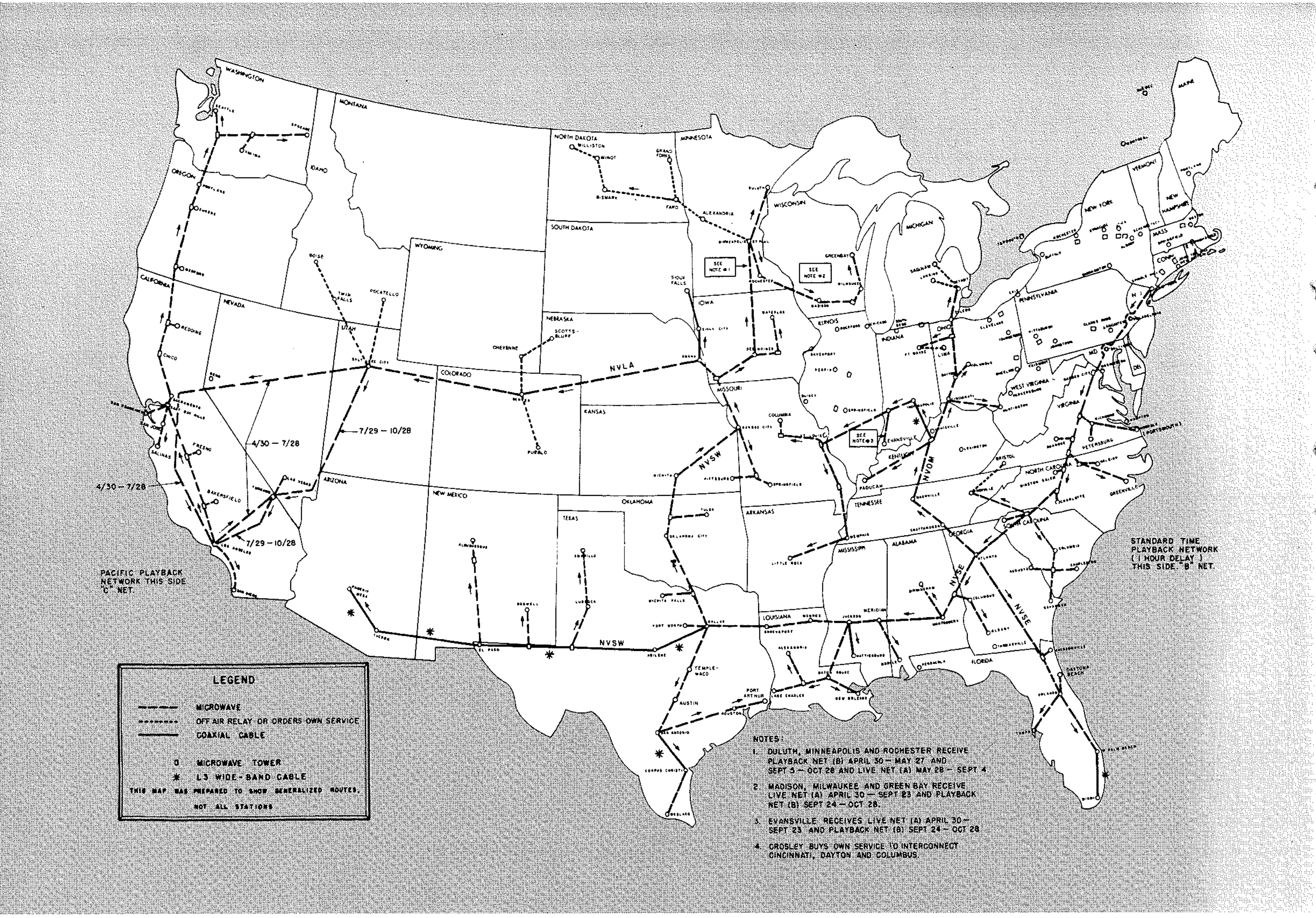
This method is convenient when many different aspects of system performance must be taken into account. Judgement plays a vital role in determining what factors are important, in the normalizing function, and in selecting weighting factors. The weighting factors involve major subjective considerations, wherein the trade-offs between performance desired and willingness to pay are incorporated. The worth concept, while not a substitute for judgement, does enhance the probability for an optimum system selection.



ROBERT G. SHUSTER received a BSEE from City College of New York and an MSEE from Columbia University. He joined the Electrical Testing Laboratories in New York in 1948 and developed procedures for precision measurement of rf characteristics of materials. Joining Sperry Gyroscope Co. in 1950, he worked on automatic control systems for aircraft and missiles. He was also closely associated with the development of a microwave command guidance system for target drones. He joined the SurfCom Systems Laboratory in 1959, working in Polaris communication studies. He is a Sr. Member, IRE.



DONALD J. BLATTNER received a BSEE and MA in Physics from Columbia University. Since joining RCA Laboratories in 1953, he has engaged in research on microwave devices and circuits, and on telecommunication systems. He has conducted courses in boundary value problems and electromagnetic wave theory at various RCA locations, and has taught TV principles at Trenton Jr. College. Author or co-author of more than two dozen talks and published papers, he is a Member of Sigma Xi, and a Sr. Member of the IRE. His IRE activities include membership in the Committee on H-F Measurements, and editorial work on Princeton Section publications.



TV TAPE AT NBC

W. A. HOWARD, Mgr. *Standards and Practices* **and** **R. MAUSLER** *Staff Engineering*
NBC, New York, N. Y.

Tape for the video recording and immediate or delayed playback of programs and commercials has proven to be a milestone for network and local TV.

One of the major problems of the TV network has been the time differentials across the nation. Now, TV tape overcomes this problem with delayed broadcasts, permitting NBC to present major programs and news services at times when the maximum number of viewers can be reached (Figs. 1, 2).

The actual production of programs and commercials can be done at a time convenient to the network, sponsors, and talent, since TV tape allows recording when facilities are most efficiently available. It is often possible to record several commercials or programs in one production that would otherwise require separate scheduling, and additional manpower and studios. In addition, many effects are possible today through TV tape which would be *impossible* to produce live (Fig. 3).

NBC began using TV tape for delayed broadcast of programs in the Burbank Television Center in 1957. Today, NBC uses forty-four TV tape recorders, sixteen by the network in Burbank, and twenty in New York. NBC's owned stations use two recorders in Washington, D.C., two in Philadelphia, and four in Chicago. These recorders are installed in pairs in a U-shape (see Fig. 4) which permits one operator to attend readily at least two recorders in recording or playback. Two recordings are taped for all network programs so a protection copy is available. These tapes are played back synchronously so that the tape or portion of the tape of better technical quality can be selected (Figs. 5, 6).

TIME DIFFERENTIAL

Because of the four time zones that produce a three-hour time differential between the eastern and western United States, it has been necessary, since the beginning of intercontinental TV network service, for NBC to maintain a delayed broadcast network for the western states.

Prior to 1957, a live show originating in New York or Burbank was transmitted at the time of origination to the eastern and central United States, while the show was being recorded on film by kinescope recording in Burbank for playback to the west-coast network three hours later. This was a very expensive and laborious process, since the film had to be developed by quick process to be ready for rebroadcast in three hours. Technical quality also suffered in the transfer of the video signal to film in the early rapid-kinescope process. This problem was compounded with the advent of color TV which required these delayed programs to be broadcast in black-and-white or out of time sequence. RCA and NBC spent considerable time on development of lenticular film, later used to delay color programs.

In the early years of its use, the taping of color TV impaired picture quality. Present-day techniques have considerably improved both picture and program quality, and engineering effort is

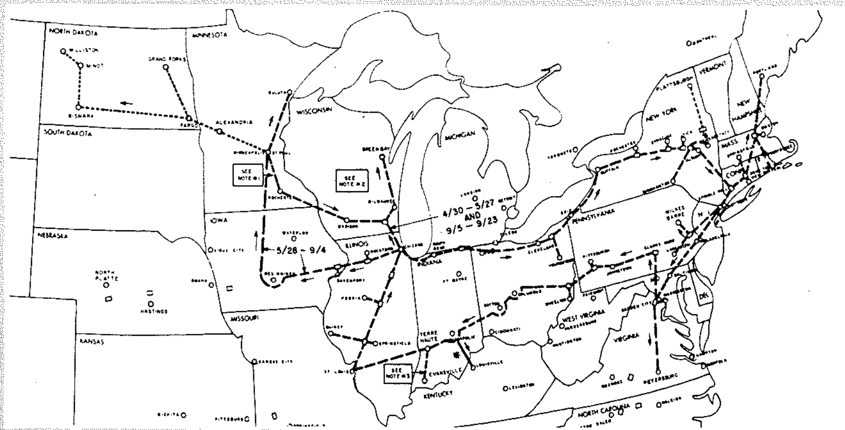


Fig. 1—(Opposite page) Map of NBC playback networks for daylight-saving time, 1961, showing generalized routes (not all stations). Pacific area is "C" net, 3-hour delay; eastern area is standard-time playback, "B" net, 1-hour delay.

Fig. 2—(Above) Map of NBC live "A" network for daylight-saving time, 1961, showing generalized routes (not all stations).

Fig. 3—A scene from Peter Pan, recorded in color for posterity on some 62,800 feet of video tape. The use of tape allowed important advantages in staging and integrating special scenes, such as this "flying sequence."

constantly directed toward further improvements in TV tape equipment and techniques.[7,8]

The problem of delayed broadcast becomes more complex during the summer months when portions of the United States change to daylight saving time.

The use of TV tape permits the NBC network to maintain programs at their normal times in these different time zones. For example, if a live show originating in New York at 8:00 P.M. during daylight saving time is transmitted to the network, without TV tape it would be broadcast in Miami, Florida, at 7:00 P.M., while most people would still be outdoors. By delaying the program one hour in the Miami area, the show can be broadcast to more viewers.

During daylight saving time, NBC operates three networks (Figs. 1, 2). At 8:00 P.M., the time of the origination of the show, the program is transmitted to the *A*, or *live network*, which covers the eastern and central areas on daylight saving time. Simultaneously, the program is being recorded on TV tape in New York and Burbank. At 9:00 P.M. New York time, the taped program is transmitted by New York to the *B*, or *repeat network*, which covers the southern and central areas not on daylight saving time. Three hours from the time of origination of the show, Burbank transmits the taped program to the *C*, or *repeat network*, which covers the western United States. A live show originating in Burbank would be transmitted to the *A* network at the time of origination and would be transmitted to the *B* network by New York one hour later, and to the *C* network by Burbank three hours later.

NEWS SERVICE

The use of TV tape by NBC has greatly expanded the potential of news services. Many news events happening during the day, which might be very difficult or impossible to film, are now recorded on TV tape and used in the evening.

For broadcasting the President's press conferences, TV tape is being used to a great advantage. This press conference usually takes place in Washington in the afternoon. The entire conference is recorded on TV tape in New York, and the entire conference or excerpts of it are played back on the network in the evening on news programs when more convenient for the public viewing.

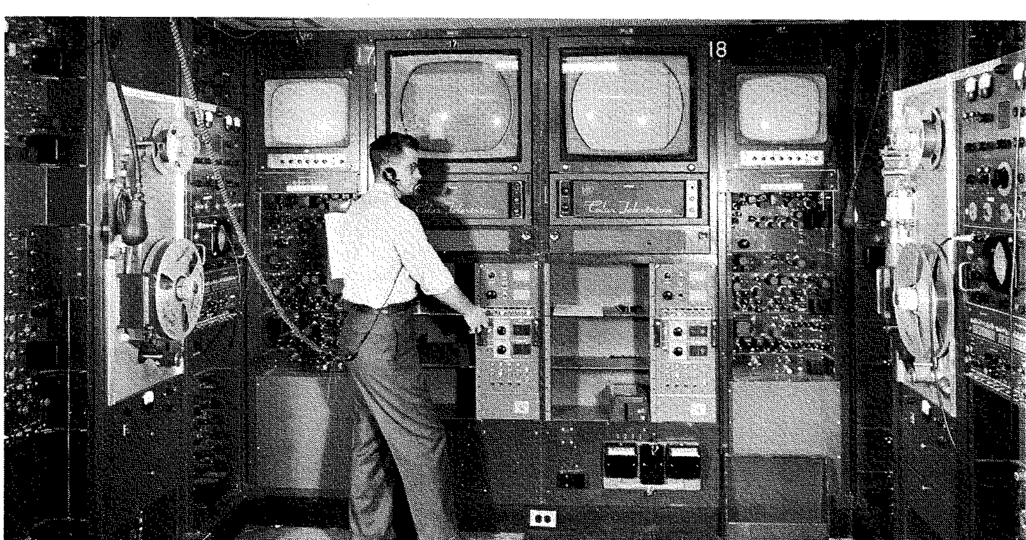
NBC has recently initiated a news service to their affiliated stations, utilizing TV tape. The network furnishes to them, on a "same-day basis," news-film coverage of events which time will not permit including in the Huntley-Brinkley report. This is accomplished by a closed-circuit feed to stations in the afternoon, Monday through Friday. Stations tape-record the incoming feed locally and utilize it in their own local programs.

TV TAPE EDITING

Editing of TV tape has been used extensively at NBC for producing shows, inserting commercials at the proper time within the show, and in news programs; however, some of the requirements have made it necessary for NBC to develop an editing system whereby the picture and sound portions can be edited separately.

This technique, a double-system recording and editing of TV tape, was developed by the NBC Technical Operations Group in Burbank and was described by Oscar F. Wick of NBC in an article in the *Journal of the Society of Motion Picture and Television Engineers*, March 1960.

Fig. 4—C. Shadel at two RCA TRT-1 AC videotape recorders in U-shaped layout at NBC, New York. Arrangement is typical of NBC installations. Standard equipment includes TM-21 color monitor, black-and-white monitor, and TO-1 waveform monitor.



This system (Fig. 7) provides simultaneous recording of the picture on TV tape and film by the kinescope recording process, and audio on 16-mm magnetic sound-track tape. For convenience in locating and matching frames on the film and TV tape, an *edit-sync* signal is recorded simultaneously on the TV tape cue track, on the kinescope-film optical track, and on a special 50-mil track on the magnetic sound tape.

The kinescope recording and the 16-mm sound track are edited to the desired show, and edit-sync pulses are tabulated where cuts are made. These cuts are easily located on the TV tape. After cuts and splices are made, the edited audio from the 16-mm magnetic sound track is dubbed to the sound track on the TV tape.

This technique has been used on numerous shows produced in Burbank, with as many as 250 successful splices being made in 60 minutes of program.

NBC-OWNED STATIONS

In the operation of NBC's five stations, TV tape has become an important factor. In addition to recording programs and commercials, programs or sport events that would not otherwise be available for the public in that area are often delayed. In the recent championship pro football game between the Philadelphia Eagles and the Green Bay Packers, the game was carried live by the NBC network. Since the game was played in Philadelphia, *WRCV-TV* in Philadelphia did not broadcast the game from the network, since the Philadelphia area was blacked out (at the request of the professional football team, to protect gate receipts). The entire game was recorded on TV tape by the station, edited to one hour, and broadcast to the Philadelphia audience the following day.

TV TAPE FOR SPECIAL SHOWS

Tape has made possible a number of shows on the NBC network that would be very difficult and, in some cases, impossible to do live. The Jack Paar Show, because of its late hour of origination, is taped in the early evening, four days a week, for playback late that night; the fifth show for Friday nights, *The Best of Paar*, is edited from these four shows. The *Today* Show is taped five days a week for playback on the network early the next morning. *Continental Classroom* is also taped in advance for playback five mornings a week.

Production Flexibility

As an example of the new production vistas created by TV tape, we have only to think of *Peter Pan*, starring Mary Martin and Cyril Ritchard. This was a two-hour show produced in color, TV-taped, and featured on the NBC network, Thursday evening, December 8, 1960.

Peter Pan had been offered twice before, live, back in 1955 and 1956, receiving wide acclaim; however, in 1960, had it not been for TV tape, the advertiser, network, and home audience would have been deprived of this classic.

The program had to be produced and shown on the network while its principal star, Mary Martin, was starring on Broadway at the Lunt and Fontanne Theatre in *The Sound of Music*. The trick, of course, was to schedule TV taping sessions outside of matinee and evening curtain times. As a result, TV taping had to be scheduled on a Monday, Tuesday, and Friday basis, with some additional taping on Thursdays for segments involving only Cyril Ritchard.

Special Effects

The *Peter Pan* story, it will be recalled, offers any live program certain problems with the flying sequences (see Fig. 4). Here, TV tape, borrowing a bit from film techniques of stop-and-go shooting, managed to obtain a smooth and continuous story presentation. Particular flying actions were easily integrated into the taping by simple camera switches; for example, to minor characters before fade out. After mechanical arrangements were completed, a recorder roll-cue and a simple fade-up provided a final viewing which appeared continuous. This type of situation might also have been approached on a tape-splicing basis. But whether splicing or prerecording segments at different times, the utmost care is required by wardrobe and set people to insure against subtle changes in clothing or set details which can become very noticeable in the whole result, but escape attention during production.

The TV tape medium, of course, has had a sensational development in quality reproduction and handling technique since the first program use for color, back on October 23, 1956.[1,2] *Peter Pan* is a show which was done in three different color studios; the Ziegfeld Theatre, located in Manhattan, and Studios I and II in Brooklyn, with the taping done over the period of nine days. Taping a two-hour show, done in three different color studios, extending over nine days, is a formidable undertaking. In addition to studio lighting problems, special precautions[3] were demanded to insure matched luminance and chroma levels at the studio control room and TV tape room, if the successive tapings were to be free of flesh-tone changes or other color differences. All line equalizers, TV tape recording heads, and other circuit equalizers were logged, in an attempt to exercise as close a control as possible over signal-transmission characteristics.

Controlling Head-Wheel and Tape Effects

Since head-wheel wear can also affect hue shift, head-wheel current optimizations had to be carefully checked periodically during the entire recording run. In this instance, it was found that head-wheel optimization currents only varied by about one milliampere.

One of the big factors causing large chroma changes are differences which occur from tape to tape. Where operational time permits adequate tape-evaluation procedures, this problem is circumvented; but otherwise, in a busy tape room this can be an important problem affecting color quality. It would not be

Fig. 5—G. Kiyak at video-tape central at NBC, New York, where monitoring is provided on all playback to "A" and "B" networks. Regular and protection copies of tapes are monitored at all times here on playback, and operator selects tape feed of best technical quality.

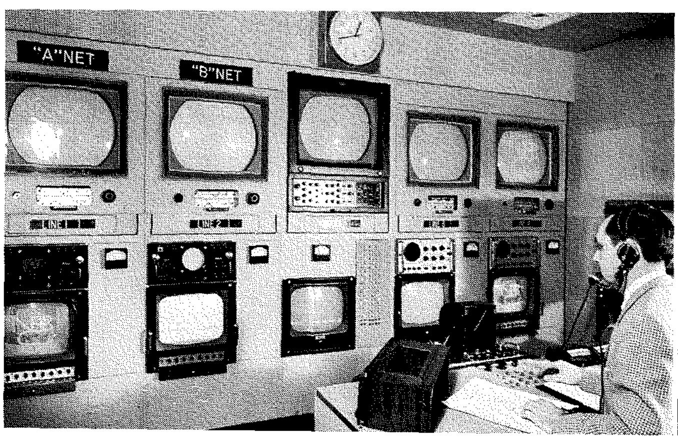
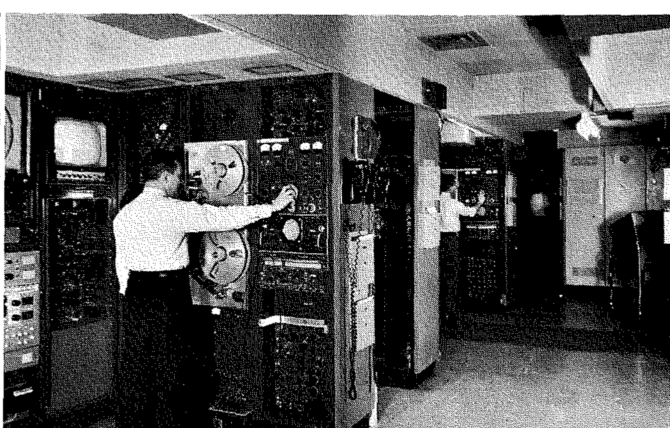


Fig. 6—A. Geisler (foreground) and J. Mills at portion of video-tape are at NBC, New York, where 20 recorders are used daily for programs and commercials to the "A" and "B" networks. Heavy schedule requires that practically all maintenance be done while off-air, 1:00 to 6:00 A.M.



unusual to have a 20-percent change in chroma level because of this tape factor.

Complementing these precautions, only the same TV tape recorders were used straight through the entire show. A different pair of machines was used for each of the show hours. The head-wheel panels themselves were assigned completely for *Peter Pan* use only and are now in a special "hold" category for later playbacks of the show.

Color Matching

To control the color match from day to day, an important and special technique was devised: A one minute recording was made of NBC's "color girl" model with a particular colored drape background, and a length of standard color bar pattern. This recording then became the criterion to which all later studio pictures were compared. Before each day's recording session, another similar recording was made, on this same tape, of the same girl, drape background and color bar pattern. By feeding this test tape back to the studio control room for evaluation, the video control engineer could then determine the necessary readjustments required in color balance to achieve a good match to the standard. The procedure was repeated until a good match was achieved. That day's recording session then proceeded, guaranteeing a close color match throughout the program.

Keep in mind that a three-degree phase shift in chroma is noticeable, and further change will rapidly affect skin tones, as will any development of differential phase distortion. Considering that 62,800 feet of TV tape were used in recording *Peter Pan* for posterity, the specifications cannot be taken lightly.

SUMMARY

The use of TV tape by the network and local stations has greatly increased operating efficiencies in both manpower and facilities. Strip shows produced for the network that required separate studios and crews five days a week, are now tape-recorded in two and a half days, with two series being produced and recorded in the same studio, using the same crew.

As a testimony to the visual quality inherent to the TV tape playback, many reviewers[4] of *Peter Pan* lauded the production and commented favorably about the color quality. Only one[5] reviewer, out of a large sample group, commented in a negative respect concerning the TV tape color rendition itself.

Complex shows can now be produced in remote locations, recorded on TV tape, edited to the desired time, and often integrated into studio productions. Recent shows on the NBC network taking advantage of this flexibility were the

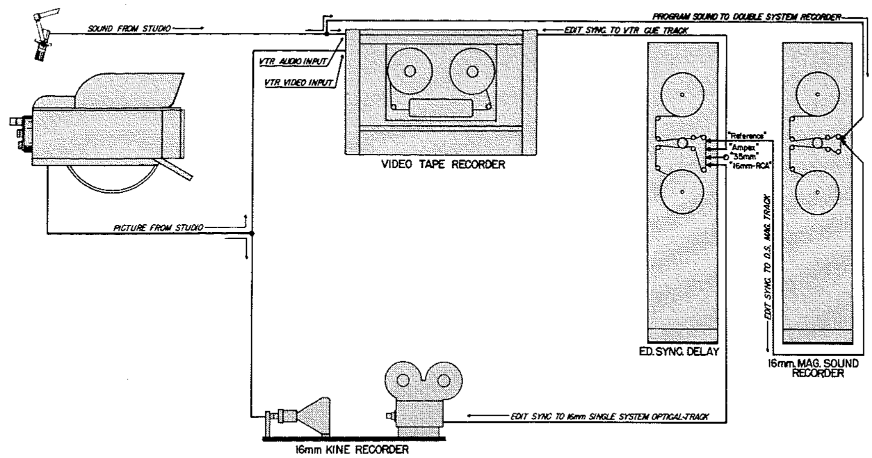


Fig. 7—Special double-system recording and editing system used for video-tape at NBC tape studios, Burbank, Calif.

Esther Williams Show and the *Roy Rogers Marine Rodeo*.

Tape offers additional advantages over film in that stop-and-go techniques can be used, perfecting each sequence by immediate playback to the production staff and talent. Elaborate electronics effects can be used, such as lap dissolves, wipes, and split screen, without going through an expensive and time-consuming printing process, as with film. Finally, TV tape has provided an excellent means of permanent storage of complex productions like *Moon and Sixpence* and *Peter Pan*.

NOTES AND REFERENCES

1. The *Jonathan Winters Show*, 10/23/56, on NBC-TV. A 2½ min. television tape segment in color, featuring Dorothy Collins.
2. The first color television tape *Progress Report* demonstration was given at RCA Laboratories, Princeton, N. J., 12/12/53.
3. For example, the same Master Control transmission engineer was assigned throughout all recording sessions.
4. Jack Gould, *N. Y. Times*, 12/9/60; George Rose, *Variety*, 12/14/60; Larry Walters, *Chicago Daily Tribune*, 12/9/60; Harry Harris, *The Philadelphia Inquirer*, 12/9/60; Television in Review, *Los Angeles Examiner*, 12/9/60; Don Freeman, *San Diego Union*, 12/13/60.
5. Bob Williams, *The Philadelphia Evening Bulletin*, 12/9/60.
6. This appellation includes such shows as *Victory at Sea, Amahl and the Night Visitors*, and the *Life of Christ*.
7. A. H. Lind, "Engineering Color Video Tape," RCA ENGINEER, Feb.-Mar. 1958.
8. J. D. Bick and F. M. Johnson, "Magnetic Heads for TV Tape Recording," RCA ENGINEER, April-May 1961.

WILLIAM A. HOWARD graduated from Howard Payne College in 1939 with a B.A. degree in Mathematics and Science and completed graduate work at Baylor University 1940-42, Mr. Howard, who has 15 years RCA engineering experience, was Mathematics and Physics instructor, and Senior Engineer at Philco for development work on "Block" Television Airborne equipment for the Army and Navy prior to joining RCA-NBC Labs in 1946. Mr. Howard is widely known in Broadcast engineering circles both for his development engineering work at NBC and his Technical Operations Supervisory Work at NBC Stations *WNBK, WTAM, WRCV* and *WRC-TV*. Mr. Howard is presently Manager of Engineering Standards and Practices, NBC, New York City. He is a member of SMPTE, AIEE, Senior Member of IRE, and Secretary of the New York IRE Professional Group for Engineering Writing and Speech. He is also NBC Editorial Representative to the RCA ENGINEER.

ROBERT MAUSLER received his B.S.E.E. from Columbia University in 1957, and continued graduate work there in pulse and digital circuits through 1958. He started with NBC in 1948 as a student engineer, continuing as a TV Maintenance Engineer at Radio City and other New York facilities. From 1955 to 1957 he was on a leave of absence to complete his studies at Columbia. He returned to NBC and in 1958 became a facilities design engineer, where he has worked on video switching systems, TV studio facilities, color camera chain equipment, and video tape. Continuous work in video tape has led to close liaison with the IEP Magnetic Recording Group in Camden. His present work involves new video-tape development and integration into NBC facilities. He has made a patent disclosure in color TV recording. His present NBC Color Quality subcommittee assignments are concerned with video tape equipment. He is a Member of the IRE.

BMEWS TRACKING RADAR

BMEWS has involved achievements in nearly every electronics discipline—but it must not be overlooked that mechanical-engineering accomplishments of equal magnitude have been made. The BMEWS radome is one such feat. Certainly, another is the antenna pedestal of the AN/FPS-49 BMEWS Tracking Radar, which operates inside the radome. In less than a year and a half, this massive, precision equipment was designed, erected, and tested. It represents a state-of-the-art among tracking radars. This ambitious project succeeded because of careful engineering of its many subsystems—a key one, the hydraulic drive, is described here. For articles on the radome and other elements of BMEWS, see RCA ENGINEER, Vol. 5, No. 6, April-May 1960.

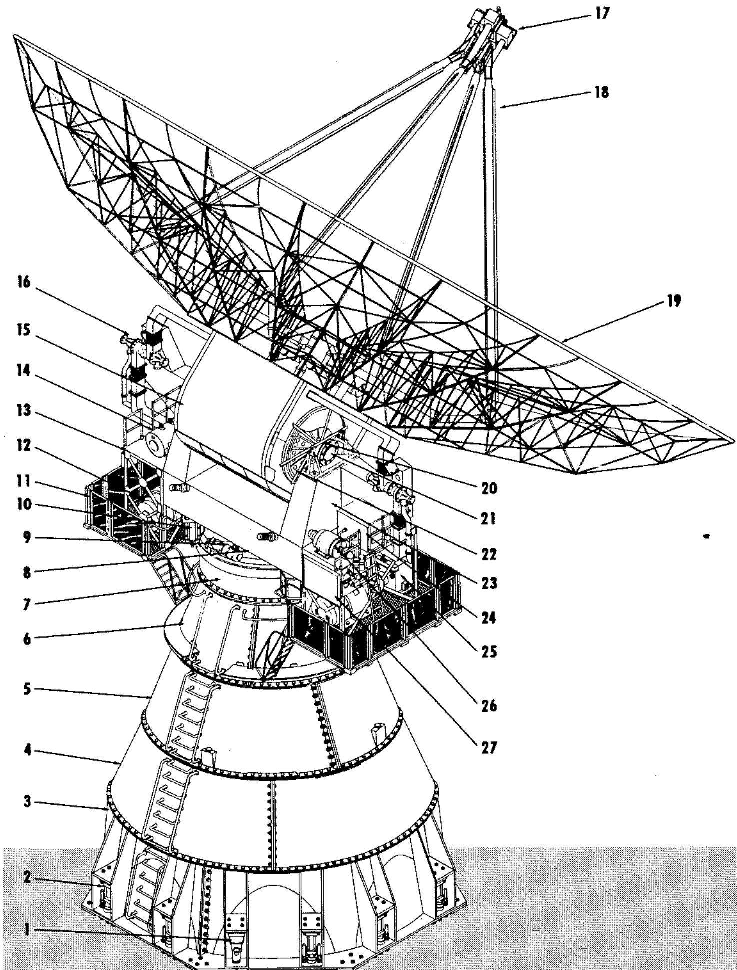
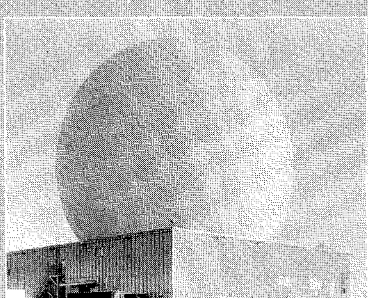
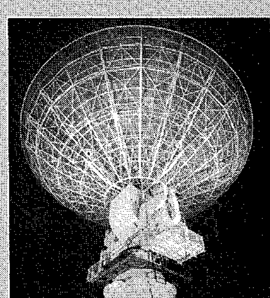


Fig. 1—Mechanical components of the BMEWS AN/FPS-49 Tracking Radar antenna and pedestal. Insets: tracking radar inside of the BMEWS prototype radome at Moorestown, and an exterior view of the radome, easily seen from the N.J. Turnpike.





1 MECHANICAL JACK
2 HYDRAULIC JACK
3 BASE
4 LOWER SUPPORT
5 MIDDLE SUPPORT
6 UPPER SUPPORT
7 BEARING SUPPORT
8 YOKE SUPPORT
9 LUBRICATION PUMP MOTOR
10 AZIMUTH HYDRAULIC TRANSMISSION (B-END)
11 EQUIPMENT PLATFORM
12 AZIMUTH ELECTRIC DRIVE MOTOR
13 YOKE ELECTRICAL EQUIPMENT
14 ELEVATION ELECTRIC DRIVE MOTOR
15 REFLECTOR SUPPORT
16 WAVE GUIDE ELEVATION ROTARY JOINT
17 FEED HORN
18 WAVE GUIDE FEED HORN SUPPORT
19 REFLECTOR
20 ELEVATION BEARING
21 ELEVATION POSITION TRANSMITTER
22 ELEVATION SECTOR GEAR
23 YOKE
24 HYDRAULIC RESERVOIR
25 AZIMUTH HYDRAULIC TRANSMISSION (A-END)
26 AUXILIARY PUMP MOTOR
27 HEAT EXCHANGER

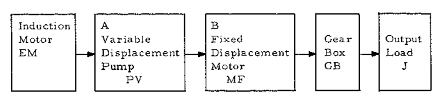


Fig. 2—Antenna drive.

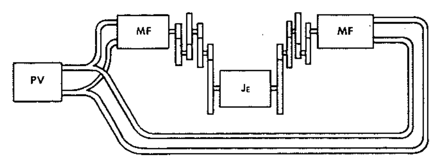


Fig. 3—Elevation main drive.

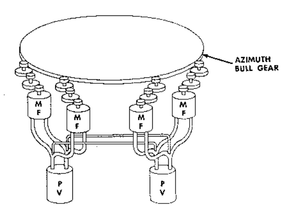
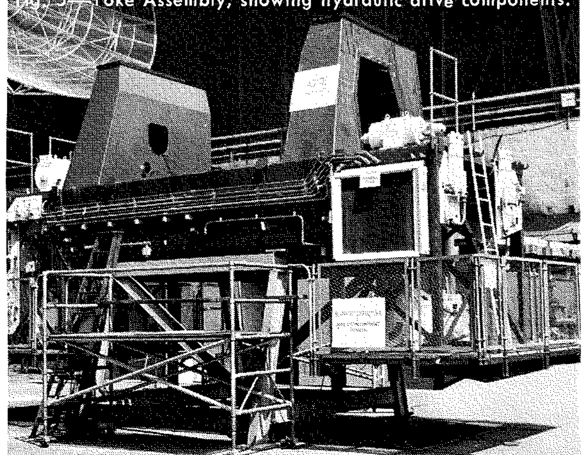


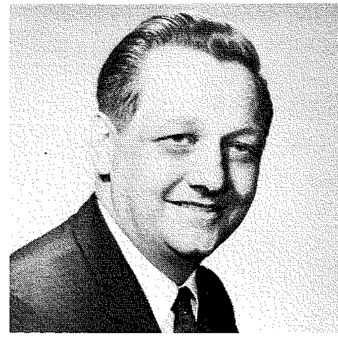
Fig. 4—Azimuth main drive.

Fig. 5—Yoke Assembly, showing hydraulic drive components.



... Hydraulic Design of the Antenna Pedestal

by **J. CARDINAL**
Antenna Pedestal Development and Design
Missile and Surface Radar Division
DEP, Moorestown, N. J.



JOHN CARDINAL joined the Precision Tracker group at DEP Moorestown in March 1957. He is a graduate of Drexel Evening College with a B.S. degree; he also attended a branch of Manhattan University where he studied related mechanical-engineering subjects. He has worked as a mechanical engineer at Strukoff Aircraft Corporation, John J. Nesbitt and Heintz Manufacturing Company. He was honorably discharged from the U.S. Navy Air Corps in July 1946 after 3½ years in anti-submarine patrol bombers. At RCA he has concentrated on the design and development of large tracking-radar antenna drives and related antenna-pedestal simulators. He is currently the assistant design project engineer on an advanced radar antenna pedestal.

THE AN/FPS-49 Tracking Radar antenna pedestal is a multi-purpose equipment—an azimuth-elevation pedestal capable of scanning for years at a time as a surveillance or detection radar. It is equally capable of functioning in an acquisition-track mode in which the radar will slew to a point, acquire a target, and track that target to provide precision trajectory data. System testing at Moorestown has proven out the final system, and BMEWS pedestals are scheduled for erection on operational sites.

From the standpoint of the antenna's hydraulic-driven system, the *scan* mode can be represented as a continuous motion of the radar at programmed velocities and accelerations. Correspondingly, the *acquisition-track* mode can be represented as long periods of standby, followed by a maximum acceleration and slew to a designated point, followed by a tracking period at low power levels in a feedback loop for a short period of time.

The long range of this radar system required an 84-foot parabolic reflector with correspondingly large inertias, capable of operating 24 hours per day with an absolute minimum of maintenance and extreme reliability.

The fact that the BMEWS Tracking Radar had so many functions to perform meant that it must not only be a jack-of-all-trades, but also a *master* of all. To the best of our knowledge there does not exist any other tracking radar with its accuracy, velocity, acceleration, and reliability. The drive parameters of the radar are listed in Table I. It is illustrated in Figs. 1-5 on the opposite page.

TABLE I—AN/FPS-49 DRIVE PARAMETERS

Description	*Azimuth*	*Elevation*
Number of drive motors	4	2
Total inertia per motor, slug-ft^2	1.73	0.30
Motor inertia, slug-ft^2	0.123	0.032
Maximum motor speed, radians/sec	124.4	94.2
Maximum motor acceleration, radians/sec^2	170	192
Static friction per motor, ft-lb	7.7	2.7
Kinetic friction per motor, ft-lb	5.8	2.0
Maximum torque per motor, ft-lb	294	57.6
Input horsepower per motor (max.)	67	10

DEVELOPMENT OF HYDRAULIC DRIVE SYSTEM AND COMPONENTS

The development of the hydraulic system began simultaneously with the production design of the antenna pedestal. As a result, a prototype hydraulic system assembled at Moorestown was only a few months ahead of the production of the pedestal components. A tight schedule such as this, with severe system requirements, dictated that standard components had to be used wherever possible. It was necessary to use four pinions in azimuth and two pinions in elevation gearing so that the torques and face widths of the gears would not be limiting factors from the standpoint of accuracy and life.

Simulator Evaluation

Two complete hydraulic-drive prototypes were assembled at Moorestown, one for hydraulic system and component evaluation, and the other for servo testing and development.

For controlled testing of the hydraulic drive, the first prototype system drove a mechanical pedestal simulator, which consisted of compliant shafts attached to each hydraulic motor to simulate wind-up in the gear boxes and a single flywheel to simulate pedestal-load inertia (Fig. 6). As system or component problems developed, corrective measures were tested or incorporated in the final hardware. As a result, a minimum number of problems in production drives have been experienced. This program will continue for some time; the later phase is devoted to the evaluation of field potential and maintenance routines.

The servo-testing prototype proved out the feasibility of the complete hydraulic servo. This large azimuth drive is believed to be the first in which four hydraulic motors in parallel were powered by two variable-displacement pumps in parallel. Correlation between the servo simulator at Moorestown and the final BMEWS antenna pedestal was established during servo testing. All production servo chassis are being finally checked out and tested on the servo simulator before being shipped to the field.

Antenna Pedestal Evaluation

The AN/FPS-49 antenna pedestals, all of which are identical, are being constructed at Goodyear Aircraft's facility in Akron. Each pedestal is being mechanically tested before it is disassembled and shipped to a site. One of the pedestals was held on its erection pad and continuously operated in a scan mode for a nine-month period. The first antenna pedestal was re-erected at Moorestown, where it is still undergoing system testing and evaluation (inset photos, Fig. 1).

Component Evaluation and Quality Assurance

Typical of component evaluation by vendors are the Vickers main drive pumps and motors.

Preliminary to the BMEWS contract, Vickers and RCA engineers evaluated the general applicability of the Waterbury-style pumps and motors for large radar servo drive application. As part of this evaluation, a size 5 *A*-end and *B*-end transmission was tested for inherent low-speed characteristics. A second series of tests (Fig. 7) was conducted at Vickers Marine and Ordnance Department in Waterbury, Conn., with a size 15 transmission. A speed range of 360,000 to 1 and speeds as low as 0.0025 rpm at the motor shaft were demonstrated. This phenomenon was repeatable with the *B*-end motor under load, under no load, and with hydraulic power derived from a mechanically locked *A*-end pump or a throttle valve. Later, as a part of the BMEWS qualification test, a size 5 transmission was started and mechanically exercised in a cold chamber after soaking at −65°F for more than 24 hours. Every production pump and motor was subjected to a rigorous acceptance test.

DESCRIPTION OF THE HYDRAULIC DRIVE

The antenna drive utilizes a constant-speed electric motor to drive an inertial output load through a variable speed hydraulic drive transmission and a mechanical gear box (Fig. 2).

The hydraulic drive incorporates variable displacement pumps or *A*-ends

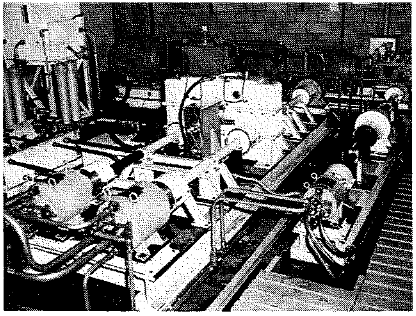


Fig. 6—Pedestal simulator and hydraulic drive.

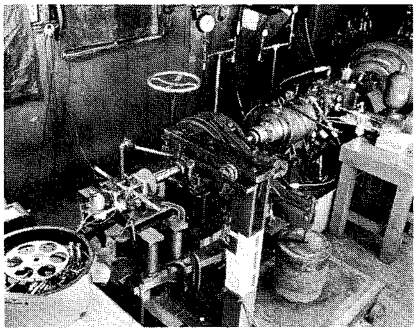


Fig. 7—Low-speed test setup at Vickers, Inc.

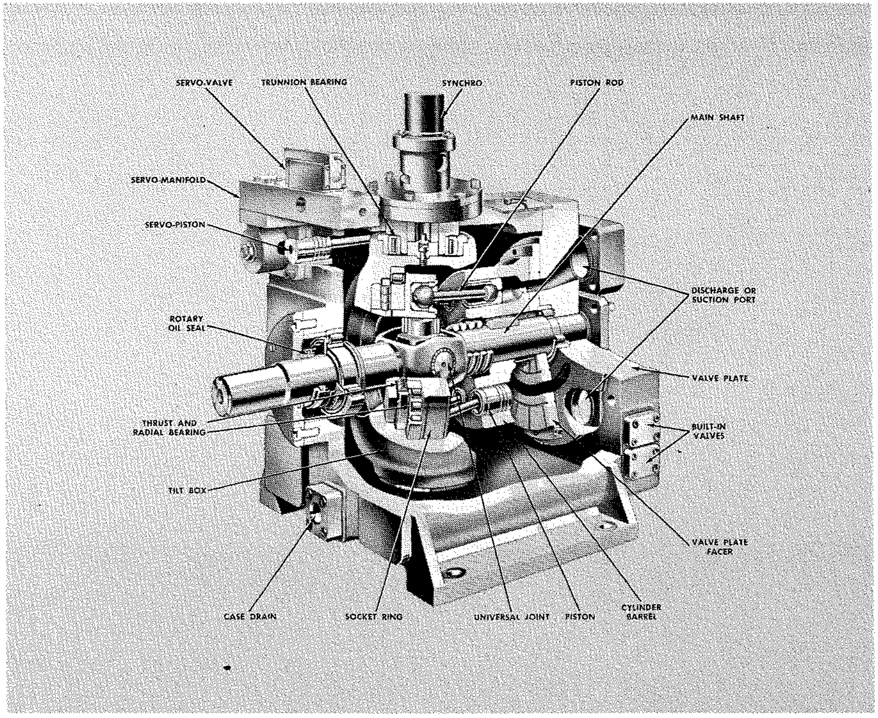


Fig. 8—A-end pump cutaway.

driven by induction electric motors. These *A*-ends supply hydraulic flow and pressure to the fixed-displacement motors, or *B*-ends. By varying the *A*-end displacement from zero to full, the *B*-ends respond and accelerate from zero to full speed. Because almost all of the radar drive load is inertial, a pressure directly proportional to the acceleration is developed in the main transmission lines. The pressure at the motors is equal to the pressure at the pumps, less the line losses.

The hydraulic drive consists of three major subsystems: 1) the *elevation main drive*, 2) the *azimuth main drive*, and 3) the *auxiliary system.*

Elevation Main Drive System

The elevation main drive system consists of an *A*-end variable displacement pump and two *B*-end fixed-displacement hydraulic motors connected in parallel so that they share the torque. Each motor drives the elevation inertial load through a separate gear box (Fig. 3). The pump contains cross-line relief valves, replenish check valves, servo pistons, and has a servo valve manifolded on it. It is driven by a 40-hp induction motor. This pump drives two Vickers axial piston motors (Fig. 8).

Azimuth Main Drive System

The azimuth main-drive system essentially consists of two groups of three main drive units (Fig. 4). As in elevation, each pump drives two motors; however, the azimuth pumps are cross-connected with smaller cross-flow lines, so that when identical servo signals are programmed to each pump, any unwanted variations in response resulting in a differential flow can be equalized in the cross-flow lines. In this way, pressure and torque differences are minimized. This differential flow is constantly monitored by a comparison of synchro position signals. The synchro-signal differences are a measure of tilt-box parallelism. The synchros are mounted on top of the pumps and are positioned by a tilt-box extension shaft.

All hydraulic components are installed on platforms attached to the azimuth turntable and rotate with it (Fig. 5). Electrical power for the drive motors is brought from the pedestal base to the azimuth turntable by slip rings. The azimuth gear trains rotate with the turntable and drive the antenna by meshing with a fixed bull-gear attached to the base of the pedestal.

Auxiliary System

The auxiliary system consists of three subsystems: 1) *control*, 2) *replenish*, and 3) *case circulation* (Fig. 9).

The control system supplies hydraulic power to the *A*-end servo valves which, as a function of servo electrical signals, control the *A*-end pumps and the entire drive. This control power is generated by a fixed-displacement gear pump.

The replenish system supplies "make-up" or replenish fluid to all main drive pumps and motors. As the main drive accelerates the load, pressure is built up in the main lines and leakage from the main drive into case circulation is replaced by replenish flow through check valves built into the main drive units. In this fashion, the replenish system maintains a minimum positive pressure in the main drive system. Thus, cavitation is prevented, and the moving parts in the rotating group of the pumps and motors are held tightly in contact. The replenish power is generated by a fixed-displacement pump and is supplemented by the overflow of excess control fluid into the replenish system.

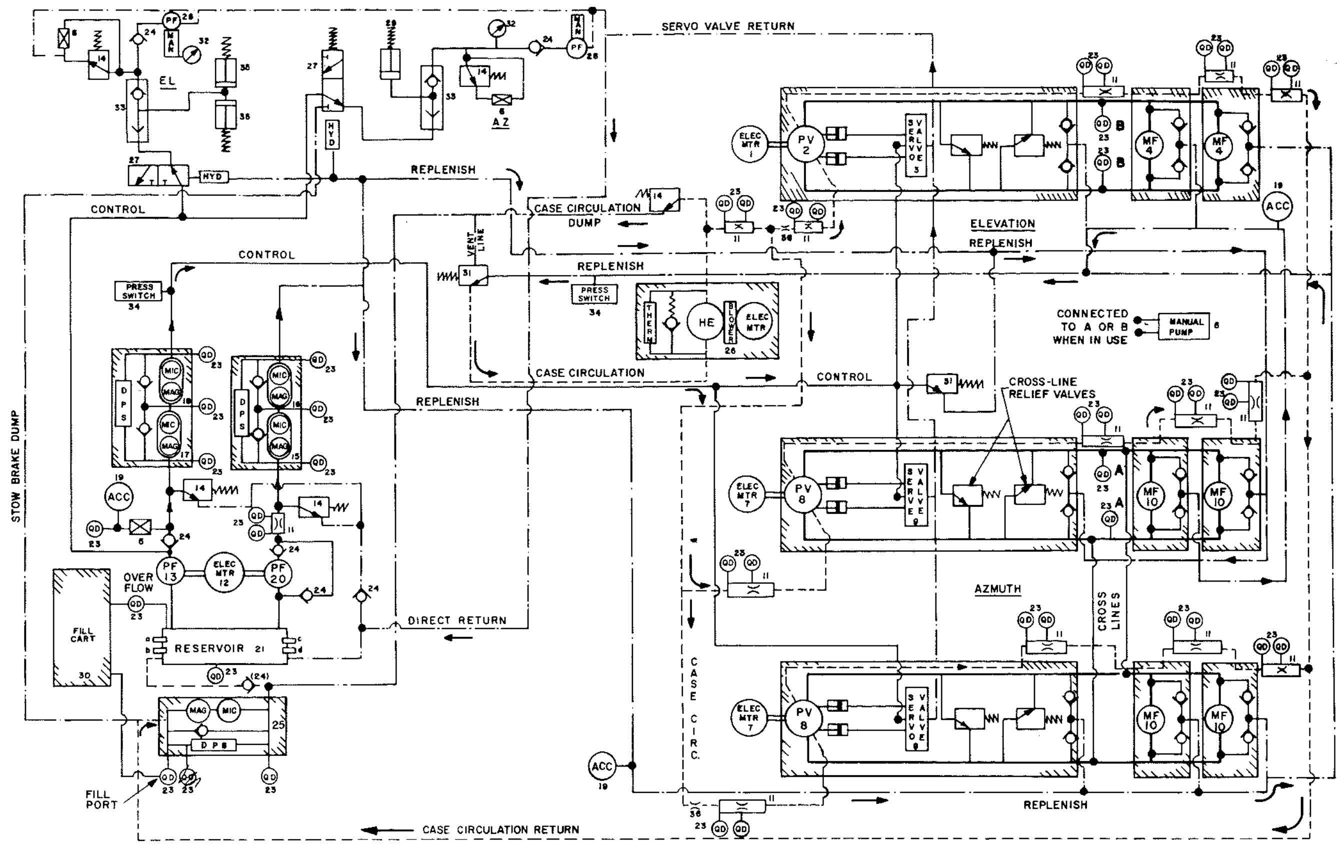
The case-circulation system power is derived from the excess replenish power overflowing into the case-circulation system. It has two functions: to lubricate the rotating groups of the pumps and motors, and to transfer heat away from the main drive. Since case circulation flows through all the *A*- and *B*-ends, and the cases are completely full, the former requirement is satisfied with a proper hydraulic-oil selection. The latter requirement is more complex and is described below.

Major Power Distribution Considerations

Fig. 10 is a block diagram of the major power-distribution considerations. Only a small part of the heat generated is dissipated by radiation through the hydraulic components and lines. This condition is made more acute by the small volume of oil in the main lines, resulting from a high hydraulic resonance requirement. A large portion of the heat produced is generated in the restricted main lines and is transferred into case circulation by conduction and leakage within the pumps and motors.

Churning losses in all the units and relief-valve pressure losses also add significantly to the heating load. The rate of heat dissipation of the heat exchanger into the ambient air is such that a maximum oil-temperature rise of 45°F can be maintained when the antenna is continuously operating in its most severe duty cycle.

Fig. 9 is a detailed schematic of the BMEWS hydraulic drive that also describes the main and auxiliary functions



1 INDUCTION MOTOR
2 VAR-DISPL PUMP
3 ELECTRO-HYD SERVO VALVE
4 HYD FIXED-DISPL MOTOR
5 FIXED-DISPL MANUAL PUMP
6 HAND OPERATED SHUT-OFF VALVE
7 INDUCTION MOTOR
8 VAR-DISPL PUMP
9 ELECTRO-HYD SERVO VALVE
10 HYD FIXED-DISPL MOTOR
11 VENTURI
12 INDUCTION MOTOR
13 FIXED-DISPL GEAR-TYPE PUMP
14 PRESSURE RELIEF VALVE
15 FILTER ASSEMBLY, REPLENISH
16 FILTER ASSEMBLY, REPLENISH
17 FILTER ASSEMBLY, CONTROL
18 FILTER ASSEMBLY, CONTROL
19 ACCUMULATOR
20 FIXED-DISPL GEAR-TYPE PUMP
21 RESERVOIR
22 VENT-FILTER
23 QUICK DISCONNECT
24 CHECK VALVE
25 FILTER ASSEMBLY, RETURN
26 HEAT EXCHANGER
27 3 WAY HYD VALVE
28 MANUAL PUMP
29 STOW BRAKE
30 PUMP & FILTER
31 PRESSURE REGULATING VALVE
32 GAUGE
33 SHUTTLE VALVE
34 PRESSURE SWITCH
35 STOW BRAKE
36 ORIFICE

Fig. 9—Details of antenna hydraulic drive.

of the system, including a complete stow-brake system. The stow brakes are mechanically held on and hydraulically released; they are released by control pressure and controlled by replenished pressure, so that if either the control pressure or replenish system fail, stow brakes are applied. The system is interlocated so that if pressure fails in each of the two mentioned systems, the main drive motors will shut off automatically.

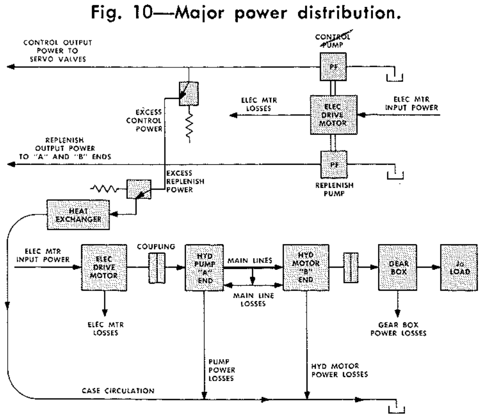
System Cleanliness

Various design features of the hydraulic drive assure a high degree of system cleanliness. A clean hydraulic system minimizes wear and assures reliability of critical components like servo valves. A change of contamination level in an undisturbed, normally clean system is a positive indication of a potential problem. This early warning can be a time- and cost-savings item, and is also instrumental in planning down-time.

The control system cleanliness requirements are: 35,000 particles between 5 to 25 microns; 2,500 particles between 25 to 100 microns; 125 particles at 100 microns; and 3 fibers. This is predicted upon 100-ml sample.

These system-cleanliness requirements are maintained by efficient full-flow filters and continuous circulation features of the control, replenish, and case-circulation systems. Thus, a contaminated system may be cleaned without opening the system.

Fig. 10—Major power distribution.



SUMMARY

The BMEWS hydraulic-drive system has been continually improved throughout its development period. Much experience and knowledge has been gained on this program, and future applications are anticipated for larger radar antenna drives.

This large, precision hydraulic equipment was designed, and the first production model erected and tested in less than 1½ years—an ambitious program that was made successful by careful planning and thought-out integration of many components and subsystems. Its high performance, reliability, and extreme accuracy—all pushing the state-of-the-art—have been proven out daily in the prototype system at Moorestown.

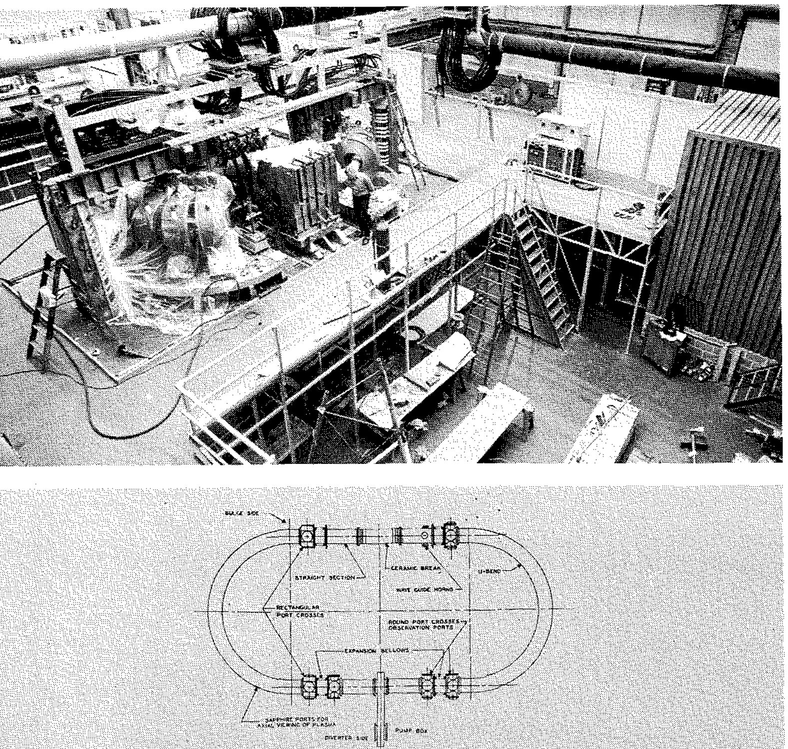


Fig. 1—The C-Stellarator during construction. Central Control room is through windows at left. The ohmic-heating coupling transformers on each end of the machine (arrows) are connected to an isolation transformer in the vault (right) by 78 lengths of 1-inch-diameter coaxial cable spirally wound around a 2-foot-diameter support. Diagram shows layout of 8-inch-diameter-pipe vacuum vessel which passes through the massive magnetic field coils seen in the photo. The ceramic break indicated in the diagram will be on the near side of the machine as it appears in the photo.

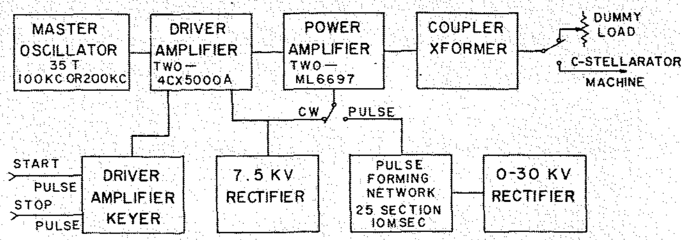


Fig. 2—B-System (breakdown heating for ionizing the fuel to form a plasma).

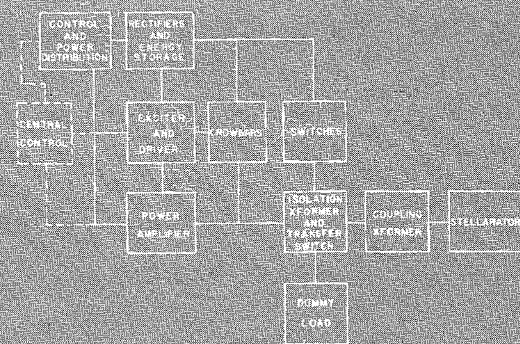


Fig. 3—OH-System (ohmic heating to raise plasma temperature to 1 million °K).

R-F TECHNIQUES FOR THE C-STELLARATOR

. . . Ionization and Ohmic Heating of Plasma for Fusion Research

by **C. D. ALLEN, G. A. SENIOR, and S. M. ZOLLERS**

Broadcast Transmitter Engineering, Broadcast and TV Equipment Division, IEP, Camden, N. J.

VITAL TO RESEARCH on controlled thermonuclear fusion are techniques for heating confined, fully ionized gases (plasmas) to temperatures of millions of °K. The use of high-power r-f energy to produce such plasma temperatures holds considerable promise[1] and has resulted in a "marriage" between the disciplines of plasma physics and high-power-transmitter engineering. The ultimate goal of this research is, of course, discovery of means of controlling thermonuclear fusion and efficiently producing electrical power therefrom.[1-5]

In this country, fusion research is being carried out under Project Sherwood[6] of the AEC. One major approach, pursued at the Princeton Plasma Physics Laboratory (formerly called Project Matterhorn) of Princeton University, has concentrated on the *Stellarator* concept[7-8]—now in its third generation with the construction of the Model-C Stellarator facility.

Through a special project group, the C-Stellarator Associates, RCA has participated jointly with the Allis Chalmers Co. in engineering and constructing the C-Stellarator.[9,10] RCA's efforts have included the ultra-high vacuum system,[11,12] timing equipment,[13] and data-handling system[14]—and the r-f schemes for plasma heating to 100 million °K.

HIGH-TEMPERATURE PLASMAS AND FUSION RESEARCH

The thermonuclear reaction of interest involves the controlled fusion of a "fuel" of hydrogen isotopes—deuterium and/or tritium—to form helium, nuclear particles, and a surplus of energy.

Conceptually, to produce a controlled fusion reaction the fuel must be ionized by heating to form a plasma, and then heated to extreme temperatures. Such heating, coupled with confinement in a given volume for sufficient time, theoretically should cause the ions to collide energetically enough to overcome the strong repulsion forces of their like charges—and thus *fuse.*

In a sense, there are two temperature conditions of concern to fusion research: *first,* to produce plasma temperatures of millions of °K for basic studies of their characteristics and the conditions necessary for fusion collisions; *second,* and ultimately, to achieve a self-sustaining fusion reaction by producing an *ignition temperature* such that the generated power in the plasma would exceed energy losses. Depending on the fuels involved and the characteristics of the reaction, such an ignition temperature may range from 100 million to 400 million °K or more.

The problem of ignition temperature, as well as many others of great challenge, must be solved before actual production of electrical power can be achieved with fusion's inherent advantages of cheap inexhaustible fuel (deuterium from sea water), safety from run-away reactions (the amount of reacting material is small), and absence of a disposal problem (the "ashes" of a complete fusion reaction are not radioactive). To date, a successful controlled-fusion reaction has not been knowingly achieved, *emphasizing the importance of concentrating on plasma research at this time.*

The C-Stellarator (Fig. 1) as a research facility, *is not intended* as a power producer or to sustain a fusion reaction. Its plasma temperatures, of the order of 100 million °K, will be provided by three heating schemes utilizing high-power r-f equipment, energized in sequence by a precision timer (called *EAST*). The "core" of the C-Stellarator is an 8-inch diameter, racetrack-shaped vacuum vessel with an axial circumference of about 40 feet. A pulsed magnetic field of up to 55,000 gauss confines the hot plasma within the vessel—a field produced by coils surrounding the vessel and energized by 12 generators of 200-Mw d-c output. Such confinement increases the probability of fusion collisions and prevents cooling of the hot plasma by contact with the vessel walls. The plasma initially must be at very low density, since outward pressure against the magnetic field increases with temperature; the plasma must also be of extreme purity to limit radiation losses from heavier nuclei impurities. Both these requirements are met by the ultra-high-vacuum system, which produces initial pressure inside the vessel as low as 10^{-10} mm-Hg.

All C-Stellarator equipments have been designed for maximum flexibility as research tools; a Central Control is provided for the great variety of experimental studies and resultant data expected.

BASIC CONCEPTS OF C-STELLARATOR PLASMA-HEATING TECHNIQUES

The r-f equipment designed and built by RCA for the C-Stellarator facility consists of three systems: *B*, *OH*, and *IH*. The *B*, or breakdown system, and the *OH*, or ohmic heating system, are now installed at the C-Stellarator facility. The *IH*, or ionic heating system, is still in the design and development stage, and so is not described in detail in this article.

Breakdown: Ionizing the Gas

The B-system output is connected across a ceramic section in the vacuum vessel as a means of ionizing, or breaking down, the gas to form the plasma. The equipment is rated to produce pulsed power up to 400 kw peak at a nominal frequency of 100 kc; however, provision is made for altering the frequency up to 200 kc, with variable frequency envisioned as a future modification. The pulse width of the B system is variable from 0.2 to 10 msec. A 70-kva CW mode of operation of this equipment is also specified for possible use in heating the vacuum vessel during the initial bake-out to aid in attainment of the highest possible vacuum.

Ohmic Heating to 1 Million °K

The OH system provides the principal heating of the test gas. Energy is coupled into the plasma by induction, since the use of electrodes that might come in contact with the gas would cool it and probably contaminate it by release of heavy ions. The induced current is expected to produce a maximum temperature of 1 million °K by I^2R losses in the plasma. The output of the OH equipment is provided by pulsed operation of six parallel-connected power tubes energized from a capacitor bank capable of 500,000 joules of energy storage. The amplitude of the output is fully adjustable to peak pulse current of 50,000 amperes in the plasma, and in pulse duration from 0.1 to 5 msec. Operation without the power-amplifier tubes is possible also, with limited amounts of the stored energy being switched by ignitrons in an over-damped discharge.

After initial C-Stellarator experiments with the r-f equipment as initially installed, even greater flexibility is to be provided by modifications. In such future operation of the OH equipment, provision is to be made for feedback control of the pulse shape from the plasma current or plasma voltage; in addition, pulses of 10-kc sine waves will be available from the push-pull connection of the power amplifier.

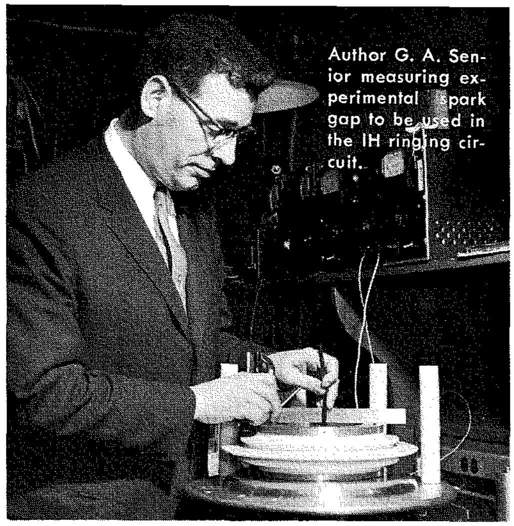
Ionic Heating to 100 Million °K

The IH system is expected to provide heating from 1 million °K to the 100 million °K level. The magnetic-pumping action involved in this type of heating is described by Spitzer.[7]

BREAKDOWN EQUIPMENT DESCRIPTION

For the gas within the C-Stellarator to be confined effectively by the magnetic field and to be heated by the r-f equipment, it must first be ionized. Ionization can be accomplished by either a d-c or an a-c voltage pulse; however, a-c is preferable because it avoids acceleration of particles to high velocities. The r-f energy above 50 kc is satisfactory for ionization and at the same time, produces relatively small net acceleration. Therefore, the B system (Fig. 2) operates at a frequency of 100 or 200 kc, as experimental conditions require.

Three air-cooled stages of r-f amplification are used in the equipment: a *master oscillator* using a 35T triode, a


Author G. A. Senior measuring experimental spark gap to be used in the IH ringing circuit.

GEORGE A. SENIOR attended the U. S. Naval Academy from 1934 to 1937 and received his BSEE and MSEE from MIT in 1940. He joined the Philadelphia Electric Co., but went on active duty with U. S. Naval Reserve in 1941. After discharge as a Lieutenant Commander in 1946, he joined RCA in the R-F Heating Group, where he worked on a coordinate translation radar. He then spent five years in Closed Circuit TV design. In 1958, he was promoted to leader and transferred to the High Power and Nucleonics Group, where he has supervised the development and design of the C-Stellarator R-F equipment. Mr. Senior is a Registered Professional Engineer (N.J.) and one of the authors of *Radar Electronic Fundamentals* and *Radar System Fundamentals*, books prepared jointly by the U. S. Navy and the U. S. Army.

C. DALE ALLEN received his BSEE in 1955 from Kansas State University. He joined RCA, on graduation, in the Acoustical Development Group of DEP Surface Communications, where he worked on AIC-10 components. In 1956, he transferred to IEP Broadcast Transmitter Engineering, where he worked on the design of uhf high-power transmitters. In 1958 he was assigned to C-Stellarator Associates in Princeton, where he has worked in the Systems Group and the R-F Group. He is a member of Sigma Tau and AIEE.

SAMUEL M. ZOLLERS graduated from Drexel Institute of Technology in 1938 with a BSEE. He joined RCA first in 1935 as part of Drexel's cooperative program and was employed by RCA for several of his periods in industry. He returned to RCA after graduation to join the Special Apparatus Drafting Group. In 1943 he transferred into the newly-formed Electron Microscope Group as an engineer. In that capacity he was engaged in all phases of electron-microscope work from advanced development through field support. In 1958 he transferred to the High Power and Nucleonics Groups, where he is currently engaged in the design, installation, and test of the C-Stellarator r-f system. He is a member of Eta Kappa Nu.


Authors S. M. Zollers (left) and C. D. Allen in front of B-System power-amplifier cabinet.

driver amplifier consisting of two 4CX5000A tetrodes in parallel, and the *power amplifier* with two ML-6697 triodes in parallel. The output power is transformer-coupled to the C-Stellarator.

The B system was designed to operate in either a continuous wave or a pulsed mode. The power output is continuously variable from 5 to 70 kva in CW operation, and from 0 to 400 kw during pulse operation.

The master oscillator operates continuously in both modes of system operation. Its self-excited Colpitts circuit has a measured frequency stability during warmup and long-time operation of less than $\pm\frac{1}{2}$ percent, more than adequate for this application.

In CW operation, the power output is controlled by adjustment of the grid bias of the driver-amplifier tubes. A motor-driven potentiometer, controllable either locally or remotely at Central Control, is used to vary the fraction of the bias-supply output voltage that is applied to the driver grids. Since both the driver and the power amplifier operate as linear amplifiers, the output power is directly controlled by this bias adjustment, because it controls the amplitude of the r-f signal effective in causing conduction in the driver tubes. The driver plate power is supplied by a 7.5-kv unitized rectifier in both pulse and CW modes of operation, but the power amplifier is energized from this supply only in CW. Tube parameters are monitored by conventional meters and by test jacks made available for oscilloscope observation.

In pulse operation, the quiescent bias on both the driver and the power-amplifier tubes is beyond cutoff. The grids of the driver are keyed to reduced bias to permit the output from the continuously-running oscillator to be amplified for a duration controlled by trigger pulses furnished by the EAST in Central Control. Experiment on previous Stellarators indicates that the desired ionization level will be produced within a few milliseconds at 1000-volt potential across the ceramic section of the vacuum vessel; however, for flexibility in the testing program, two modes of pulsing have been provided: a *normal mode*, in which the pulse length may be varied from 0.2 to 10 msec at a repetition rate up to 3 pulses/min.; a *rapid mode* in which the pulse length may be varied from 0.2 to 1.0 msec at a repetition rate of 10 pulses/sec.

The keyer circuit consists of a multivibrator, a cathode follower, and a keying tube. The multivibrator is a conventional cathode-coupled, monostable

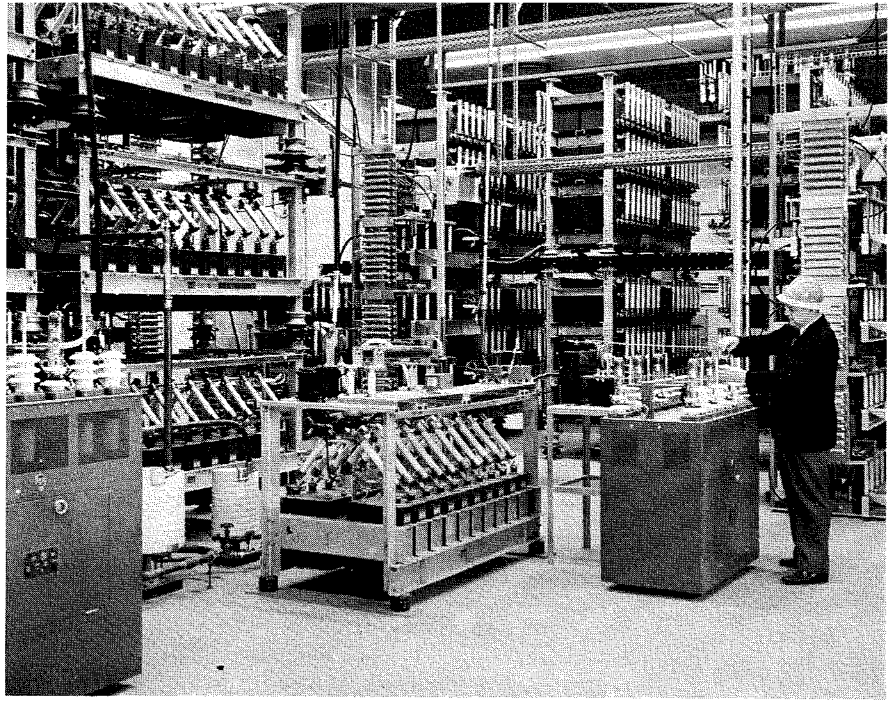


Fig. 4—R. Smith examines the power-amplifier bias supply in the OH Energy Storage Room. At left, reaching toward ceiling, is one 9-μf, 60-kv capacitor bank. In center is 1000-μf energy storage for anodes of the OH driver. At right, six of the 4500-μf capacitor groups (stacked two high) provide background for two crowbar stacks.

circuit set for a constant 10-msec output pulse. The time at which the pulse is initiated is controlled by the *start* pulse from the EAST. The width of the pulse applied to the system may be shortened by the application of a second, or *stop*, pulse also generated by the EAST. The rectangular waveform generated at the normally *on* plate of the multivibrator is coupled by the cathode follower to the keying tube to prevent loading from affecting the multivibrator. The keying tube is connected as part of a voltage divider across the bias power-supply voltage, with the plate of the keying tube grounded and the driver grids connected to its cathode. Thus, the plate- the r-f signal only when the keying tube is the bias voltage applied to the driver, so that the drivers are able to amplify the rf signal only when the keying tube is driven to low plate resistance by the positive pulse generated by the multivibrator.

In both the normal and rapid modes of operation, the pulse rise time is 50 μsec, measured at 90 percent of peak value. The time foı the trailing edge of the pulses to decay to 5 percent of peak value is 15 μsec, which is only one and a half periods at 100 kc. Since the required *Q's* of the tuned resonant circuits of the r-f stages are too high to permit such a short decay time, loading resistors are switched in at the end of the r-f pulse. Hydrogen thyratrons are used as switch tubes to provide loading to the pi-coupling network in the driver output and to the tuned primary of the output transformer. These thyratrons are fired by the stop pulse, causing the energy in the tuned circuits to be quickly dissipated in the resistors switched in for this purpose at the same time that feed of further energy is stopped by the termination of the keying pulse.

In the pulse operation of the system, the plate power for the power amplifiers is supplied from a 25-section pulse-forming network. In the *rapid* mode of pulse operation, only five sections of the pulse-forming network are used, with the whole line being used in the *normal* mode. The network is charged from a 3-phase voltage-doubling rectifier to a voltage adjustable between 0 and 30 kv. When the line is terminated in its characteristic impedance of 300 ohms, it is capable of supplying a constant 50 amperes at 15 kv for 10 msec.

During the process of ionizing the test gas in the C-Stellarator, the load presented to the power amplifier changes radically. The 100-kc impedances are likely to pass through the range of $0.01 + j5.0$ ohms initially, to $1.25 + j1.25$ ohms, and finally to $0.1 + j1.25$ ohms when the gas is fully ionized. Transformer coupling is used to match the high impedance of the power-amplifier tank circuit to this low load impedance range. All testing has been done into the dummy load provided in the system at a nominal impedance of $1.25 + j1.25$ ohms; also, operation into the extreme impedances has been thoroughly tested by modifying the dummy load. A motor-operated load-transfer switch connects the secondary of the coupling transformer to either the dummy load or to the C-Stellarator.

OHMIC HEATING EQUIPMENT DESCRIPTION

The power amplifier is the pivotal point of the OH system (Figs. 3, 4, 5), since the rest of the design is influenced strongly by the choice of power-amplifier tubes. Developmental A15030 superpower beam triodes, having a peak pulse power output rating in the order of 20 Mw, are employed. This tube has a designed capability for instantaneous plate voltage of 50 kv and peak pulse cathode current of 660 amperes at normal rated filament temperature.

The duty cycle is small (0.01 maximum) so the average plate dissipation of the tubes is well below ratings. The 840-ampere peak cathode current, which may be required per tube, is beyond anticipated emission capability at rated filament temperature. Provision has been made to "pulse up" the filament voltage to raise the temperature to 2075 °C to provide the required emission.

Early experiments to be performed require that the OH system produce a pulse of current in the plasma which is: 1) fully adjustable in magnitude to a peak value of 34,000 amperes; 2) adjustable in duration from 0.1 to 5 msec; 3) to have the rise and fall of a 5-kc sine wave; 4) to have pulse repetition rates up to 3 per minute with full pulse width, or 10 pulses/sec with 1-msec maximum duration.

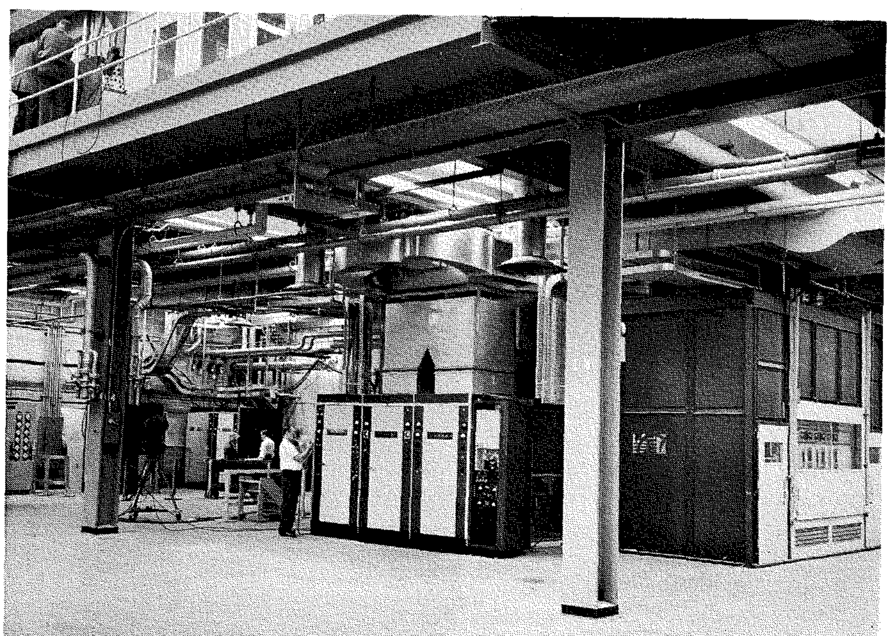
Provision has been made for pulsing the plasma current as high as 50,000 amperes to permit investigation of theoretically predicted instability. Under conditions for obtaining this higher-current pulse, rise time is limited to 0.22 msec and maximum repetition rate is 3 pulses/min.

The large amount of stored energy needed to produce the current pulse requires that the power amplifier tubes be protected from fault damage. A fault-detection circuit is employed which is insensitive to the normal voltage pulses appearing at the grids and cathodes of the tubes. The fault-detection circuit reacts to a difference in voltage developed between the tubes when a fault occurs in one of them. The signal developed by the fault-detection circuit is applied to crowbars on the energy-storage banks and on the secondary of the isolation transformer so as to divert nearly all energy from the faulted tube. Tests indicate that the crowbars fire less than 4 μsec after a fault signal occurs.

Drive for the grids of the power amplifier is obtained from a cathode follower consisting of twenty-four 4CX5000A tubes connected in parallel. These have a combined transconductance of nearly 1 mho and peak power-output capability of 400 kw in this application. The energy for the pulse is obtained from a 5-kv, 1000-μf capacitor bank which serves as a plate-power supply for the cathode followers. The 12,500 joules stored in this bank are diverted from a fault in the cathode followers by a single 5555 ignitron crowbar. The cathode follower is driven by a series of class-A voltage-amplifier stages, the last of which is a group of four 4CX5000A tubes.

An exciter provides a reference pulse shape; its timing and duration are determined by pulses from the EAST at Central Control, or if desired, by a local timer. Provision has been made for the use of feedback to produce the desired shape of current pulse.

Fig. 5—The OH driver and power-amplifier area, with B-System control cabinets in background. Front panel of one power amplifier carriage forms portion of one wall of power-amplifier enclosure. On second-floor balcony, technicians observe interior of OH energy-storage room through safety-glass windows.



The output of the power-amplifier tubes is coupled to the plasma through two types of transformers: A pair of coupling transformers that use the plasma as the secondary turn, mounted on the machine, and a transformer in the plate circuit of the power-amplifier tubes that affords voltage isolation and a choice of two impedance transformations through a tap changer. To reduce lead inductance, this switch is mounted under oil in the isolation-transformer case. This switch also provides for either clockwise or counterclockwise induced current in the plasma at both turns ratios.

Two power-amplifier carriages have been provided with space for five tubes on each carriage, although three tubes per carriage are expected to deliver the required power to the plasma. Each tube is housed in an insulating enclosure containing a gas of high dielectric strength so that voltages may be handled that are nearly twice the maximum instantaneous rating of the tube. In addition to the tubes, the carriages support the filament transformers, filament voltage controls, insulating water coils, and tube fault-detection and indicator circuits related to each of the power-amplifier tubes. Voltmeters and ammeters for filament power, flowmeters for the cooling water for plates and grids, and the water-supply header are mounted on a 9-by-7-foot panel bolted to the front of each carriage.

The connections between the energy-storage capacitor banks and the isolation transformer, and between the isolation transformer and the power-amplifier tube plates have been made coaxial to reduce the lead inductance. This is desirable because it reduces the voltage drop in the inductance of the connections and, therefore, reduces the level of high voltage needed in the system. The coaxial structure near the tubes must withstand the same voltages as the plates of the tubes themselves. Air was selected for the dielectric for this coaxial line, designed to withstand a peak operating voltage of 90 kv. However, no safe means of connecting the tube plates to the inner conductor of the coaxial line was apparent. Therefore, a transition section was designed to permit the short section of the line nearest the power-amplifier tubes to be operated with the inner grounded and the outer at high voltage. This unusual arrangement greatly facilitates connecting the tube plates in parallel, since they are disposed in a circle around the line. No operating hazard results from this connection, since the entire power amplifier is enclosed in a shielded enclosure.

A load-transfer switch on the isolation transformer permits connection of the secondary winding to a dummy load or to 78 parallel lengths of RG19A/U coaxial cable. These cables provide a low inductance connection between the isolation transformer and a pair of transformers mounted so that the vacuum vessel passes through the window of their cores. Thus, the plasma is the secondary winding of these coupling transformers. The coupling transformers are connected with their primaries in parallel, but the single-turn of plasma (the secondary turn common to both transformers) has the induced voltage from the two transformers effectively series-aiding.

Plate-supply voltage for the power amplifier is derived from two separate rectifier systems. These rectifiers may be independently adjusted to meet the various requirements of the experiments to be performed.

The low voltage supply (rated at 3 kv, 50 amperes) may be connected to a bank of capacitors arranged in nine groups of 4500 μf each. With all nine groups in parallel, the resulting 40,500 μf stores the main portion of the energy requirements for first-stage experiments. The groups of capacitors can be rearranged from parallel to series connection by removing a pair of connectors at each group. With the bank so arranged, the total capacitance is 500 μf; the bank may be charged to 45 kv with a resultant energy storage of over 500,000 joules.

A pair of 9-μf capacitor banks can be charged, by a pair of high-voltage rectifiers, as high as 60 kv. The high voltage from this bank of capacitors is applied to the plates of the power-amplifier tubes to obtain the desired rate of rise of current in the inductance of the system.

Type 5555 ignitrons are used as high-voltage switches and high-current crowbars in unusual combinations of series and parallel connection. These ignitrons are a notable example of application of available components to meet requirements outside of their published ratings. The ignitrons, designed for rectifier, welder, or control service, are rated for 2400-volt maximum forward voltage and for 6000-ampere maximum peak current. It has been found by experiment at the Princeton Plasma Physics Laboratory that these ignitrons will withstand at least 15 kv in forward or reverse directions, and up to 70 ampere-seconds in high-current discharges. Advantage has been taken of these facts in connecting five ignitrons in series to provide a suitable crowbar for the high-voltage capacitor banks. A peak current of 60,000 amperes may be expected, but this is within the ampere-second rating of the ignitrons.

Two switches, each consisting of five ignitrons in series, connect the high-voltage capacitor bank and the low-voltage capacitor bank to the plate circuit of the power-amplifier tubes. These switches must withstand a voltage of 60 kv each and pass a peak current of 5000 amperes. Their operation is controlled by timing pulses from EAST.

Crowbars for the nine groups of 4500-μf capacitors consist of eight ignitrons connected in parallel or series arrangements, as may be required.

SAFETY PRECAUTIONS

The r-f equipment for use at the C-Stellarator facility is intended for experimental use by physicists and others who may not necessarily be familiar with its associated hazards. In addition, large amounts of stored energy must be available to produce the high pulse-power level needed in the experiments. Therefore, the safety requirements of this installation are more severe than for ordinary broadcast equipment. All access doors and panels are interlocked in the conventional way, and the status of the interlock system is summarized at both Local and Central Control. Access to all areas in which contact is possible to conductors that may connect to the stored energy is by means of a system of key interlocks requiring that all power be turned off to make a key available. This key must be used to unlock a grounding switch which, when locked in the *safe* position, makes available another key that permits entry into the energy-storage area. Emergency *off* buttons are available in various places throughout the building to remove all power if needed. The connection of the B and OH system outputs to the C-Stellarator is by means of motor-operated load-transfer switches that must be cycled to the dummy load position, in which no output energy can be fed to the C-Stellarator, before access is gained to the C-Stellarator room.

The power to the r-f equipment is 480-volt, 3-phase, from two 1000-kva transformer banks; 300 kva of this power is regulated to 1 percent for filament supplies and other critical applications. The power supplied to the high-voltage plate-voltage supply for the power amplifiers of the OH equipment is furnished from a separate 500-kva transformer bank to provide added isolation of the stored energy in case of fault.

SUMMARY

The B system has been fully tested into its dummy load at 100 kc in both the cw and pulse modes. The OH System has been driven to a current of 500 amperes per tube for 1 msec at this writing. Both systems were made available for experimental use in the C-Stellarator facility in early 1961.

ACKNOWLEDGEMENTS

The authors wish to acknowledge the contributions to the development and design program of the many people associated with it; particularly C. J. Starner, J. Q. Lawson, N. J. Oman, and J. H. Roberts.

BIBLIOGRAPHY

1. E. W. Herold, "Controlled Thermonuclear Fusion—Its Meaning to the Radio and Electronic Engineer," *RCA Review,* Vol. XIX, No. 2, p. 162; June 19, 1958.
2. George Warfield, "Controlled Thermonuclear Fusion—Promise of the Future," *RCA Review,* Vol. XIX, No. 2, p. 137; June 1958.
3. P. T. Smith, "Controlled Thermonuclear Fusion," RCA ENGINEER, Vol. 4, No. 5; Feb.-Mar. 1959.
4. R. F. Post, "Controlled Fusion Research—An Application of the Physics of High Temperature Plasmas," *Proc. IRE,* Vol. 45, No. 2, pp. 134-160; Feb. 1957.
5. Dr. M. P. Bachynski, "Plasma Physics—Part I: Natural Phenomena and Thermonuclear Fusion" RCA ENGINEER, Vol. 6, No. 5, p. 30; Feb.-Mar. 1961.
6. A. S. Bishop, *Project Sherwood—The U.S. Program in Controlled Fusion:* Addison-Wesley Publishing Co., Inc.; 1958.
7. Lyman Spitzer, Jr., "The Stellarator," *Scientific American,* Vol. 199, No. 4, p. 28; October 1958.
8. Robert A. Ellis, Jr., "Stellarator," *Princeton Alumni Weekly,* Vol. LIX, No. 1, p. 6; September 19, 1958.
9. J. Q. Lawson, "The Model C Stellarator," RCA ENGINEER, Vol. 4, No. 5; Feb.-Mar. 1959.
10. Dr. L. B. Headrick, "Design of the C-Stellarator," RCA ENGINEER, Vol. 6, No. 5, p. 6; Feb.-Mar. 1961.
11. K. Dreyer and J. T. Mark, "The Ultra-High-Vacuum System for the C-Stellarator," *RCA Review,* Vol. XXI, No. 4, Dec. 1960.
12. K. Dreyer and J. T. Mark, "Ultra High Vacuum—C-Stellarator System Involves Advanced Techniques," RCA ENGINEER, Vol. 6, No. 5, p. 14; Feb.-Mar. 1961.
13. P. E. Slavin, "Equipment Action Sequence Timer—Precision for the C-Stellarator," RCA ENGINEER, Vol. 6, No. 5, p. 19; Feb.-Mar. 1961.
14. A. S. Buchman and R. T. Ross, "Data Handling for the C-Stellarator," RCA ENGINEER, Vol. 6, No. 5, p. 11; Feb.-Mar. 1961.

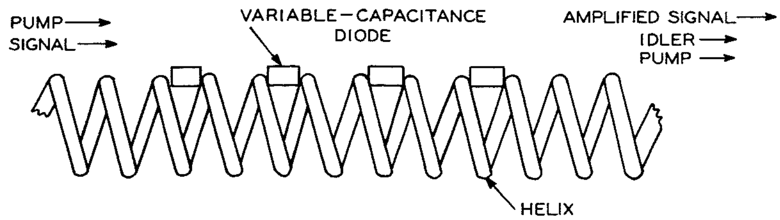
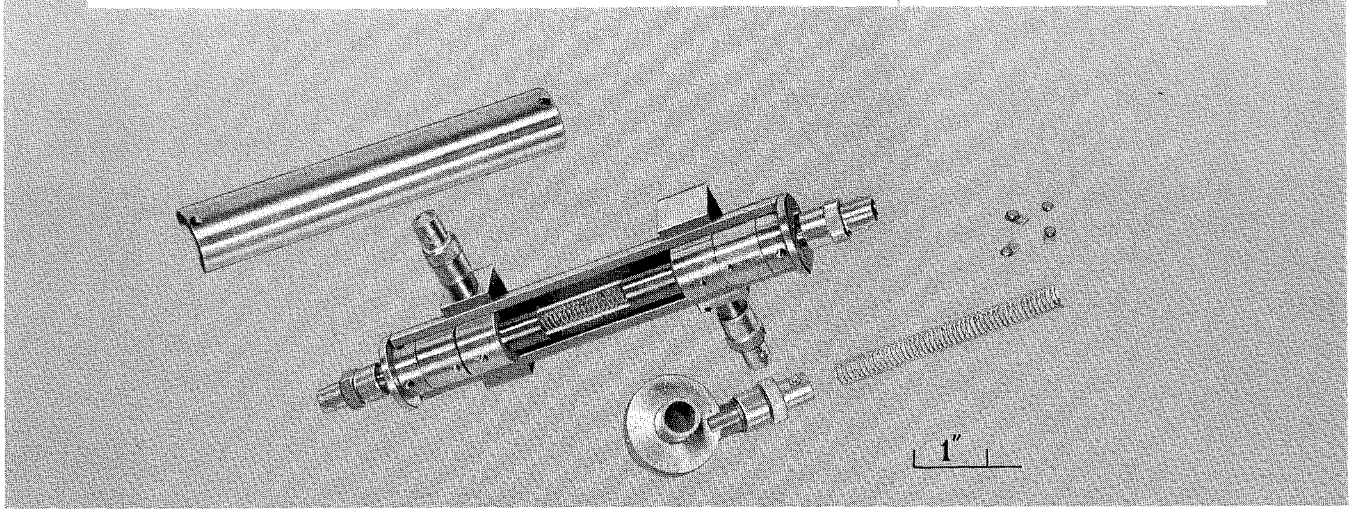


Fig. 1—Basic circuit structure of a diode-loaded helix parametric amplifier which uses variable-capacitance diodes as shunts for selected helix turns.

Fig. 2—Below: An experimental helix parametric amplifier. The connectors along the capsule axis (left and right) are for pump signal and termination respectively, and the connectors perpendicular to the capsule axis are to the input and output helical couplers respectively. At bottom are typical circuit elements: helix, helical coupler, and "pill"-type variable-capacitance semiconductor diodes.



A MINIATURE-PACKAGE 2200-MC PARAMETRIC AMPLIFIER USING A VARACTOR-LOADED HELIX

by **C. L. CUCCIA, Mgr.**
West Coast Microwave Engineering Laboratory
Electron Tube Division
Los Angeles, California

A MINIATURE-PACKAGE parametric amplifier of a new type has been designed for operation in the 2200-Mc band. This amplifier, which uses several varactors as periodic variable-capacitance loads for a helix, differs from conventional parametric-amplifier circuits using resonant circuits and stubs and a single varactor.

The input signal and pump signal are applied to the start of the helix, and the amplified input signal is derived from the end of the helix. A pump signal having a frequency approximately 30 percent higher than the input-signal frequency is used, and harmonic generation of the pump signal is utilized within the parametric amplifier to provide noise-figure reduction. The amplifier is operated as a four-terminal device, and provides an insertion loss of approximately 30 db at input-signal frequency between the input and output terminals when the pump is off. No circulator is required.

This parametric amplifier comprises a packaged structure included in a capsule 1 inch in diameter and 5 inches long, and weighs only 5 ounces. One form of this amplifier provides for a net input-terminal-to-output-terminal gain of 20 db with a noise figure of less than 5 db in the 2200 to 2300-Mc band. Operating data demonstrating instantaneous bandwidths of up to 100 Mc in this frequency range are included herein.

THE HELIX PARAMETRIC AMPLIFIER

The helix parametric amplifier represents a new approach to solid-state parametric amplifiers using a varactor-diode-loaded helix.[1] This unique filter circuit has exceptional features as a microwave-frequency low-noise amplifier having increased bandwidth and exceptional gain stability, and a structure readily adaptable for circuit miniaturization.

This new helix parametric amplifier operates in the 2200-Mc frequency range with bandwidths up to 5 percent, and amplifies with noise figures of the order of 5 to 6 db.

The miniature helix parametric amplifier has a slightly higher noise figure than bulky one-port parametric-amplifier-and-circulator combinations, which amplify with noise figures in the range of 2 to 4 db. In many microwave systems, however, reduction in package size and weight is mandatory, and the ultimate in lowest noise figure is not required.

AMPLIFIER STRUCTURES

The basic amplifier structure is a helix in which semiconductor varactor (variable-capacitance) diodes are distributively coupled (Fig. 1). The varactor diodes are employed as variable-capacitance shunts to selected helix turns; the signal to be amplified, and a pump signal are applied to the input section of the helix; the amplified version of the applied signal is derived from the latter part of the helix.

Despite the use of the helix type of slow-wave structure, this amplifier is *not* a traveling-wave parametric amplifier of the type in which interactions take place over a large number of wavelengths of the signal frequency. The interactions of the signal, pump, and idler frequencies are accomplished in the few turns of the helix where diode loading is employed; the portions of helix preceding or following this interaction region function as input and output circuits. The helix parametric amplifier operates with characteristics similar to those of a cascaded band-pass filter, with the loaded turns functioning as broad-band parallel-impedance elements and the helix turns between as coupling elements.

Fig. 2 shows the principal components of the helix parametric amplifier; a length of helix, a helical coupler capable of coupling to the helix over wide frequency ranges, and variable-capacitance semiconductor diodes housed in an RCA-developed miniature pill-type structure.

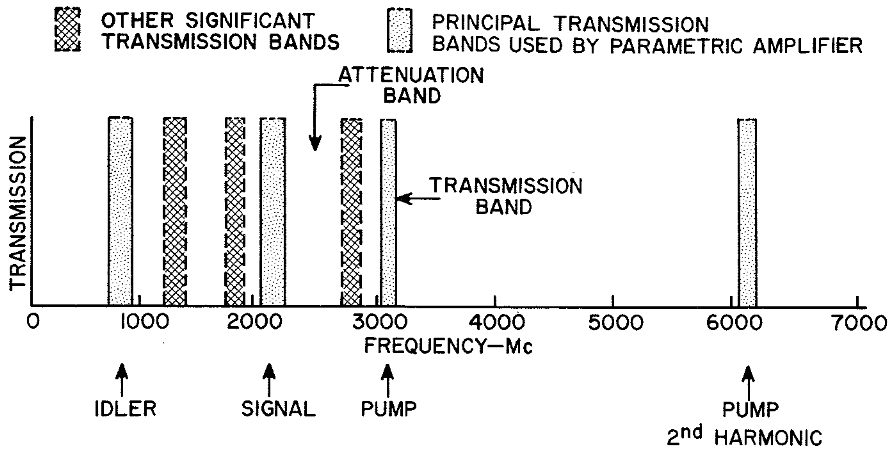


Fig. 3—Attenuation-vs-frequency characteristics for the helix of Fig. 2, illustrating some of the stop and pass bands produced by loading the helix with three diodes.

Semiconductor variable-capacitance diodes of the type shown in Fig. 2 were used as helix-turn loading elements. These germanium diodes have capacitances of the order of one picofarad, and are encapsulated in small cylindrical packages having a diameter of approximately a tenth of an inch and a thickness equal to the interturn distance.

The helical coupler used in the helix parametric amplifier simplifies the technique of multiple-signal coupling to and from the helix and has three major features: 1) it is a very small structure; 2) it is capable of coupling to a helix over a range of several frequency octaves; and 3) it is basically a directional coupler, coupling energy to the helix to propogate only in the direction of the coupler helix. This type of coupler is widely used in traveling-wave tubes because of its excellent low-VSWR coupling characteristics. Its use in the helix parametric amplifier provides means for coupling the pump and input signals to the helix with a great degree of mutual signal isolation, although the insertion loss of the input helical coupler is somewhat higher than that of other types of couplers using waveguides or coaxial cavities.

Fig. 2 shows an experimental helix parametric amplifier which uses three diodes in the helix turns, helical couplers for coupling the signal to be amplified to and from the helix, and a direct connection to the helix for the pump signal. Amplification is accomplished in the very small exposed region without the use of tuning stubs or a multiplicity of circuit structures or narrow-band elements.

In the helix parametric amplifier, the applied signal and the pump signal interact successively in each diode-loaded helix turn to generate an idler signal at the difference frequency of the applied and pump signals. Amplification is obtained at the signal and idler frequencies by conversion of power from the pump.

The small number of shunting diodes can be used very effectively because the unusual filter characteristics of the diode-loaded helix structure make it possible to develop higher voltages and provide increased stored energy in the helix turns. In addition, the pump frequency is less than twice the signal frequency, the gain rises to a maximum value and then decreases with increasing pump power, and no regions of oscillation are encountered.

The mechanical simplicity of the circuit elements used contrasts sharply with the precision required of these elements. As in traveling-wave tubes, minute eccentricities in turns per inch of the helix can produce substantial changes in its transmission characteristics. The helical coupler also must meet critical tolerances to maintain coupling in desired frequency bands located many hundreds of megacycles apart.

PASS BANDS OF THE DIODE-LOADED HELIX

Helix structures periodically loaded with elements which are electrically nonvariable have been used by Dodds and Peter[2] for the enhancement of gain in a traveling-wave tube, and by Siegman and Johnson[3] for the suppression of backward waves in a traveling-wave tube. However, the use of loading elements which periodically load the helix and also produce amplification is novel.

The unloaded helix is well known to be a slow-wave structure which is nondispersive over very wide ranges of frequencies encompassing a number of frequency octaves. Such unloaded helices, when wound with low-loss materials and supported in non-dissipative structures, are capable of providing signal translation with very low insertion loss.

When the helix is periodically loaded by impedance elements, it becomes dispersive and develops a pattern of transmission bands and stop bands. In the transmission bands, the stored energy per length of helix is greatly increased by the periodic loading.

Fig. 3 shows the typical attenuation-versus-frequency characteristics of the helix used in the parametric amplifier shown in Fig. 2; this helix is periodically loaded by three diodes. As indicated, pass bands representing attenuation of the order of 20 to 30 db are located approximately 300 Mc apart, and a pass band of very low insertion loss is located at 3000 Mc.

For operation of the helix parametric amplifier, the pass bands at 800, 2200, and 3000 Mc were chosen for idler, signal, and pump, respectively. The relatively small frequency range separating these three frequencies makes the use of a helical-coupler output circuit very attractive because the helical coupler can couple to the helix at each of these frequencies with low VSWR.

CIRCUIT OF THE HELIX PARAMETRIC AMPLIFIER

The circuit aspects of the helix parametric amplifier are based on one straight forward requirement: the amplified input signal, a pump signal of reduced intensity, and the idler signal, all produced in the output of the amplifier, *must be terminated in proper impedances.*

Fig. 4—Block diagram of the circuit used for testing the gain characteristics of a helix parametric amplifier over the frequency band from 2200 to 2300 Mc.

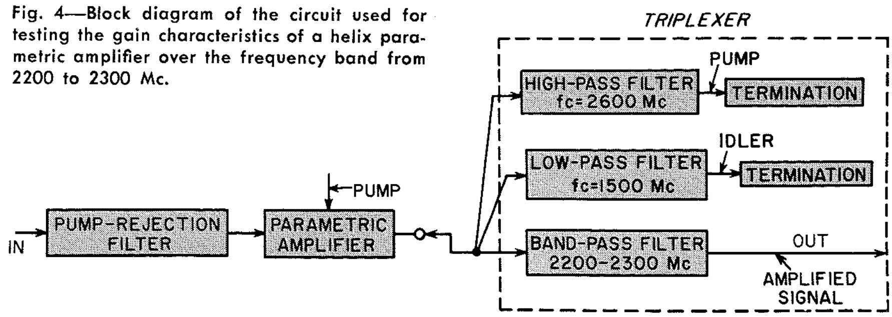


Fig. 4 shows the basic circuit arrangement used for operation in the 2200-to-2300-Mc frequency range with a pump frequency of 3000 Mc. The input signal is applied through a low-loss pump-rejection filter to the amplifier input. The pump signal is also supplied to the amplifier input, although the input is designed to provide for decoupling between the input signal and pump input.

The output circuit is a triplexer type of arrangement. The output of the parametric amplifier feeds into a power divider having three output circuits. One output circuit couples to a band-pass filter which passes the band of frequencies that have been amplified on to the next circuit. The second output couples to a high-pass filter suitable for coupling the remaining power at the pump frequency to a matched termination and for rejecting both the amplified-input-signal and idler-signal power. The third output couples to a low-pass filter having a cut-off frequency between the low frequency of the idler signal and the input-signal frequency; a matched termination is provided at the output of the low-pass filter as a termination for the idler signal.

In the circuit of Fig. 4, the band-pass filter in the output circuit passes only the desired 2200-to-2300-Mc band; the high-pass filter in the output pump circuit has a cut-off frequency at 2600 Mc; and the low-pass filter in the idler output circuit has a cut-off frequency at 1500 Mc.

OPERATING CHARACTERISTICS

Fig. 5 illustrates gain characteristics of the helix parametric amplifier for various fixed values of pump power and frequency. For a pump frequency in the vicinity of 3000 Mc and a pump power of 500 mw, peak values of more than 20 db of gain are obtained. The gain peaks can be located in various parts of the 2200-to-2300-Mc frequency band by variation of the periodic diode spacing. Asymmetrical spacing of the diodes permits instantaneous bandwidth across the entire 100-Mc band (not shown).

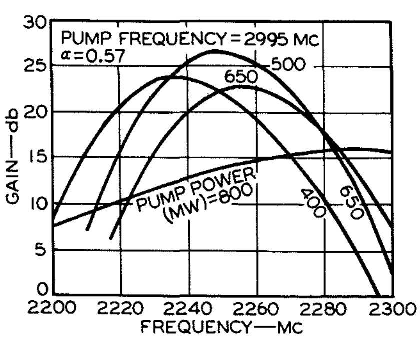


Fig. 5—Gain-vs-frequency of a parametric amplifier for several fixed values of pump power.

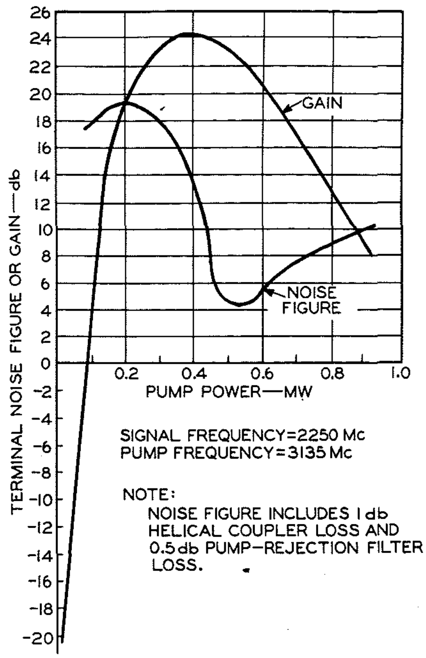


Fig. 6—Noise figure and gain as functions of pump power for a helix parametric amplifier.

Gain characteristics were measured under small-signal conditions with signal inputs at less than −30 dbm. In general, the three-diode helix parametric amplifier is saturated at power-output levels greater than 1 mw, depending upon diodes used, the diode arrangement, and the amount of pump power required at the frequency of signal amplification.

Curves of noise figure and gain as functions of pump power are shown in Fig. 8 for operation at 2250 Mc. As indicated, the noise figure is high in regions of low pump power and gain, but decreases as the pump power is increased to the maximum-gain level. This behavior is similar to that described by Knechtli and Weglein.[4] In the maximum-gain region, the terminal noise figure passes through a minimum of about 4.5 db. If pump power is increased beyond the region of maximum gain, the noise figure then increases while gain decreases.

The total noise figure of 4.5 db is contributed primarily by the second harmonic of the pump signal, produced by harmonic generation in the first diode, but also includes losses due to the input circuit, helix losses, and losses in the diode. The noise-figure contribution due to the second-harmonic mode of operation is single-channel because noise components at the idler frequency in this mode of operation are entirely rejected by the pump-rejection filter.

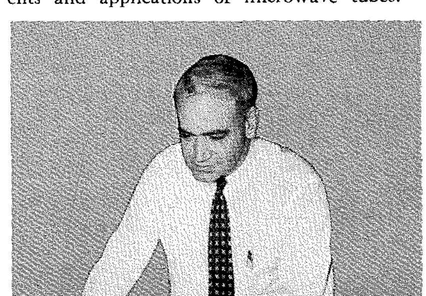
In general, the experimental helix parametric amplifiers tested have not been self oscillatory at any pump frequency or power, except under conditions of severe output-circuit mismatch. This tendency to remain nonoscillatory persisted in all modes of operation tested, including modes requiring as much as 1 watt or as little as 2.5 mw of pump power for substantial gains, and operation at pump frequencies in pass bands other than those providing maximum gain characteristics.

The characteristic behavior of the helix parametric amplifier with the gain rising to a peak and then decreasing with increasing pump power, as shown in Fig. 6, is due to the start of conduction of the diodes near the peak-gain condition. Increased diode conduction and increased resistance shunting of the diode-loaded helix turns result as the pump power is increased beyond the maximum-gain point.

BIBLIOGRAPHY

1. K. K. N. Chang, G. Conrad, and R. Hughes, "The Diode-Loaded Helix as a Microwave Amplifier", *Proc. IRE*, May 1960.
2. W. J. Dodds and R. W. Peter, "Filter-Helix Traveling-Wave Tube", *RCA Review*, December 1953.
3. A. E. Siegman and H. R. Johnson, "Suppression of Backward-Wave Oscillation by Filter Helix Methods", *IRE Transactions on Electron Devices*, April 1955.
4. R. C. Knechtli and R. D. Weglein, "Low Noise Parametric Amplifier", *Proc. IRE*, July 1960.

C. LOUIS CUCCIA received the B.S.E.E. in 1941 and the M.S. in 1942, both from the University of Michigan. From 1941 to 1942 he was also employed as a Research Engineer for the GM Fisher Body Division to investigate high-frequency welding of aluminum. He joined RCA Laboratories in 1942 and worked on microwave-tube research and development until 1954. His work included the first 2J41 magnetron, new FM magnetrons, injection-locked grid-controlled magnetrons, and high-power transverse-field traveling-wave tubes ("electron couplers"). In 1952, McGraw Hill published his book *Harmonics Sidebands and Transients in Communication Engineering.* From 1954 to 1957, he was assigned to the color-TV activity of the RCA Patent Department, specializing in the evaluation and patenting of new color-TV receiving circuits. Early in 1957, he joined the Microwave Operations of the Electron-Tube Division as Engineering Leader in charge of traveling-wave-tube and backward-wave-oscillator design and development. In 1959, he became responsible for the product development of varactor and tunnel-diode signal sources and amplifiers, and in January 1961, he was named as Manager of that Division's new West Coast Microwave Engineering Laboratory in Los Angeles, to provide product development of solid-state microwave components and applications of microwave tubes.



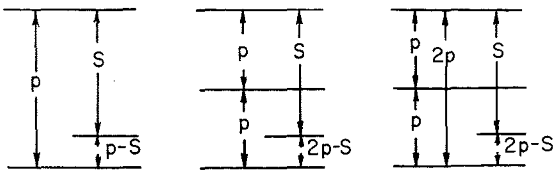


Fig. 1—Three parametric amplifier pumping schemes (l. to r.): a) CONVENTIONAL; pump, *p*, signal, *s*, and idler, *p-s*, voltages are each supported by tuned circuits; b) LOWER-FREQUENCY; three tuned circuits at *p*, *s*, and 2 *p-s*; no circuit at 2*p*; c) HARMONIC PUMPING; a fourth tuned circuit is needed to support pump harmonic at 2*p*.

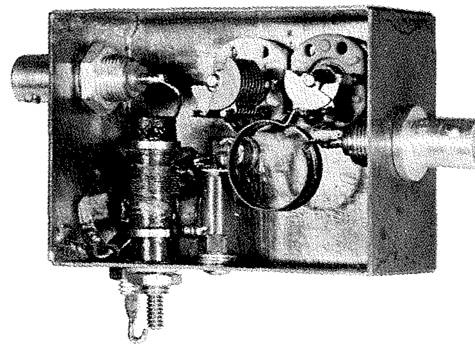


Fig. 4 — UHF lumped-circuit tunnel-diode down-converter.

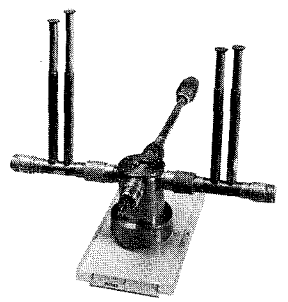


Fig. 2—Coaxial-line parametric amplifier. Signal circuit resonates at 6.6 kMc, pump circuit at 4.0 kMc.

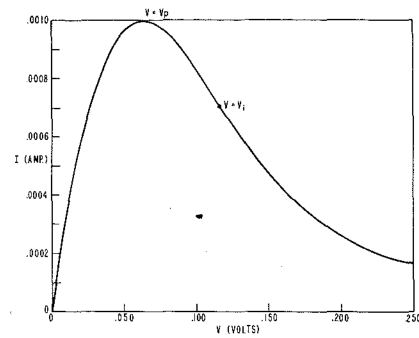


Fig. 3—*I-V* characteristic of a Ge tunnel diode.

The conventional low-noise parametric amplifier usually requires an ac pump, with frequency many times higher than the signal — a stringent limitation on operating frequency, since a higher-frequency pump is not always practical; a lower-frequency pumping scheme, verified experimentally, is described. The negative-resistance characteristic of tunnel diodes can be used for frequency conversion with gain; exceptional low-noise and reasonably broad bandwidths have been measured on a recent uhf lumped-circuit tunnel-diode down converter.

SOME RECENT RESEARCH IN PARAMETRIC AND TUNNEL-DIODE

by **Dr. K. K. N. CHANG**

RCA Laboratories

Princeton, N. J.

SOLID-STATE DEVICES in the microwave field are commanding keen attention —the parametric and tunnel-diode amplifiers, in particular, since at room temperature they yield low noise factors at high microwave frequencies.

The conventional low-noise parametric amplifier usually requires an ac pump, the frequency of which is many times higher than that of the signal. This immediately sets a stringent limitation on the operating frequency in view of the fact that a higher-frequency pump is not always practical. To remedy this, a lower-frequency pumping scheme was suggested at RCA Laboratories.[1] This scheme has received wide interest both as a straight amplifier and as an up-converter.

Among the tunnel-diode devices, the tunnel-diode down-converter has been a particularly interesting subject. Ordinary crystal mixers, utilizing the nonlinearity of their prospective resistances, exhibit conversion losses and poor noise factors. The parametric converters, operating on the basis of a nonlinear capacitance or inductance, have achieved good noise factors with up-conversion gain. The parametric down-converters, however, have poor noise factors. The unusual negative resistance characteristic of tunnel diodes can be utilized for frequency conversion with gain. Under certain conditions, a tunnel-diode down-converter also yields good noise factors.[2]

LOWER-FREQUENCY PUMPING

A p-n junction diode, when biased in the reverse direction, exhibits a voltage-dependent capacitance. In an abrupt junction, this capacitance varies inversely as the square root of the applied voltage. If the capacitance C is expanded in a Taylor series about the biasing point $V = V_o$, it can be written

$$C = C_o\left[1 - \frac{\hat{V}}{2(V_o + V_e)} + \frac{3}{8}\frac{\hat{V}^2}{(V_o+V_e)^2} - \frac{5}{16}\frac{\hat{V}}{(V_o+V_e)^3} + \cdots\right] \quad (1)$$

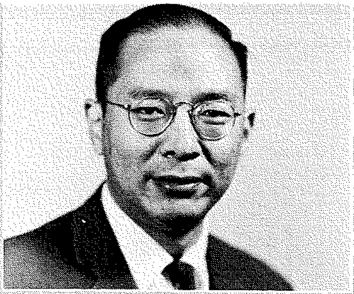
Where: V is the applied voltage and V_e is the contact potential of the diode. Numerically, V_e is of the order of a few tenths of a volt.

The charge is the product of the capacitance and the voltage. Accordingly, from equation 1, the equation for the charge q is

$$q = C_o V - \frac{C_o\hat{V}^2}{2(V_o+V_e)} + \frac{3}{8}\frac{C_o\hat{V}^3}{(V_o+V_e)^2} - \frac{5}{16}\frac{C_o\hat{V}^4}{(V_o+V_e)^3} + \cdots \quad (2)$$

Equation 2 shows the nonlinear relationship between the charge and the voltage. The first term is the linear term. The other terms are nonlinear and so can be utilized for parametric amplification. While the conventional parametric amplifier uses an even-order nonlinearity to mix a pump of frequency p with a signal of frequency s to form the lower sideband at p-s, the lower-frequency pumping scheme uses instead an odd-order nonlinearity. (Fig. 1).

Fig. 1a shows a typical conventional parametric amplifier with three frequencies. To support these three frequencies, the required minimum order of nonlinearity is the first. The lower-frequency pumping scheme (Fig. 1b) operates in a different manner. The circuitry is again a three-frequency model; however, since the lower sideband frequency is $2p$-s, the mixing action necessitates the second order of nonlinearity. Such a mixing action is not to be confused with the harmonic pumping shown by Fig. 1c. The harmonic-pumping scheme uses both frequency multiplication and mixing. It operates with the *first-order* nonlinearity and requires a physical resonant circuit to support the $2p$ harmonic. Because of its need for a fourth resonant circuit, the harmonic-pumping scheme requires a much higher pumping power than lower-frequency pumping.



DR. K. K. N. CHANG received the B.S. from National Central University, Nanking, China in 1940, the M.S.E.E. from the University of Michigan in 1948, and the D.E.E. in 1954 from the Polytechnic Institute of Brooklyn. From 1940 to 1945, he was with the Central Radio Manufacturing Works, Kunming, China working on radio receivers, and from 1945 to 1947 he was a radio instructor with the O.S.S. in China. Since 1948, he has been with RCA Laboratories, Princeton, engaged in research on magnetrons, traveling-wave tubes, and microwave solid-state devices. In 1953 he did original work on periodic field focusing for traveling-wave tubes, which has culminated in an RCA commercial line of TWT's. In 1957 he was one of the pioneers who explored the principle of parametric amplification, and harmonic generation. In 1958, when the tunnel diode was introduced, he was first to realize a low-noise tunnel-diode amplifier and converter. Dr. Chang is a member of Sigma Xi.

AMPLIFICATION

The use of different orders of nonlinearity for the mixing interaction can be controlled by the circuitry. It may happen that various even-order (or various odd-order) terms of equation[2] all contribute to the mixing interaction at the same desired frequency. In that case, the mixing output will be the vector sum of all the contributions. In practice, however, the contribution from the higher-degree terms is small and can be ignored.

A parametric amplifier based on the lower-frequency pumping scheme has been built. The amplifier, which uses coaxial lines as the resonators, has a signal frequency of 6.6 kMc, a pump frequency of 4 kMc and an idling frequency of 1.4 kMc (Fig. 2). Gains as high as 25 db were obtained. More recently, the principle of lower-frequency pumping has been verified at other laboratories and has been used to obtain 11.63-kMc oscillation with a 11.03-kMc pump.[3]

TUNNEL-DIODE DOWN-CONVERTER

Nonlinear resistances or reactances have long been used for frequency conversion. With the exception of parametric-diode mixers, conventional mixers exhibit a conversion loss. The recent introduction of tunnel diodes has made possible frequency conversion with gain. This new feature is due to the unusual quasi-parabolic *I-V* characteristic of the tunnel diode.

As shown in Fig. 3, the curve is linear near the origin. However, the curve is quadratic about the peak ($V = V_p$) and is approximately linear, with a negative slope, about the inflection point ($V = V_i$). By inspection of the characteristic, it is apparent that the logical biasing region for frequency conversion should be near the peak and the proper bias for the tunnel-diode amplifier is near the inflection point.

Assume the useful range of the *I-V* curve to be from $V = -20$ mv to $V = 120$ mv. Around the peak point, the characteristic can be represented by

$$\hat{I} = G_o\hat{V} + G_1\hat{V}^2 + G_2\hat{V}^3 + \cdots \quad (3)$$

For a typical germanium tunnel diode *I-V* characteristic, such as is shown in Fig. 3, biased at $V = 50$ mv, the coefficients have the following values[4]: $G_o = 4.602 \times 10^{-3}$ mhos, $G_1 = -213 \times 10^{-3}$ mhos/volt, and $G_2 = 1522 \times 10^{-3}$ mhos/volt^2.

The dominant nonlinear term in equation 3 responsible for mixing the signal frequency and the pump frequency to form the IF is the quadratic term. The cubic nonlinear term gives rise to an additional fundamental frequency term which can be comparable in size to the G_oV term if the driving voltage V is high enough. There is also a dc rectified current resulting from the even order of nonlinearity, that is, from the V^2 term and, to a lesser extent, from the V^4, V^6 . . . terms. In order not to shift the operating bias, a stiff bias (i.e. a very low dc resistance biasing circuit) should be used. In most practical cases, where the pumping voltage is small, say in the order of 50 mv, the cubic and higher-order terms can be ignored.

Because of its parabolic *I-V* characteristic, the tunnel-diode converter can give conversion gain. This can be visualized qualitatively as follows: Suppose the biasing point to be near the peak and on the positive slope side. If the applied pump voltage is large enough to cause a sufficient swing into the negative-slope part of the curve, then in half of the pump cycle, the pump sees an average net negative resistance. The pump would thus supply extra energy to the output through mixing action and enables the down-converter to achieve a conversion gain. In ordinary mixers having an over-all nonlinear positive resistance, the pump energy is all dissipated in this positive resistance; thus, conversion is accompanied by loss.

Down-conversion with gain is preferable to down-conversion with loss, since it permits a lower over-all noise factor. The ordinary (i.e. lossy) mixer usually has a relatively high noise factor, most of which is due to the IF noise because of the conversion loss. With conversion gain, however, it is reasonable to expect that the tunnel-diode converter should yield low noise factors. By excluding the IF noise, as a result of the conversion gain, the question remains: *what is the source and magnitude of the noise left in the diode converter?* The noise has been confirmed to be shot noise; however, it has not been determined whether or not this shot-effect noise has a "space-charge reduction factor" analagous to that found in vacuum tubes.

Recent experiments on a lumped-circuit tunnel-diode down-converter (Fig. 4) yield results as follows[5]:

dc biasing diode current = 0.95 ma
RF input frequency = 615 Mc
IF output frequency = 30 Mc
conversion gain = 6 db
bandwidth = 6 Mc
image rejection = 3 db
pumping voltage = 70 mv
noise factor, single sideband = 4.5 db

These noise measurements were performed by two alternative methods: with a noise source, and with a signal generator. Results agreed reasonably well.

In recent measurements on tunnel-diode down-converters, a reduction of noise factors has been observed. In particular, lower noise factors have been achieved through application of relatively high pump voltages. To explore these reductions, the previous "small-pump" analysis of the tunnel-diode down converter[2] is now being extended to include the effect of large pump voltages.

CONCLUSION

In summary, the method of lower-frequency pumping affords a means of extending the low-noise parametric amplifier to higher and higher frequencies using practical pump generators. The tunnel-diode down-converter has the unique property of yielding low noise and high gain.

BIBLIOGRAPHY

1. S. Bloom and K. K. N. Chang, "Parametric Amplifiers using Low-Frequency Pumping" *J. Appl. Physics*, Vol. 29, p. 594, March, 1958.
2. K. K. N. Chang, G. H. Heilmeier and H. J. Prager "Low-Noise Tunnel-Diode Down Converter Having Conversion Gain" *Proc. IRE*, Vol. 48, No. 5 pp. 854-858, May, 1960.
3. L. U. Kibler, "Parametric Oscillations with Point Contact Diodes at Frequencies Higher Than Pumping Frequency" *Proc. IRE*, Vol. 48, No. 2 pp. 239-240; Feb., 1960.
4. Calculated by A. H. Simon, Computer Group, RCA Laboratories.
5. Experimental results obtained by H. J. Prager, RCA Laboratories.

OPERATION OF VIDICONS IN SPECIAL ENVIRONMENTS

by **G. A. ROBINSON**
Electron Tube Division
Lancaster, Pa.

A risk to a vidicon, by exceeding its standard ratings, may be justified in special applications. Discussed herein are effects on performance of faceplate temperatures and illuminations above maximum ratings, high pressures, and nuclear radiation.

TESTS HAVE BEEN run on commercially available vidicons to determine performance under special conditions of faceplate temperature and illumination above maximum rating, high pressures, and nuclear radiation. The results are discussed herein. This data *does not imply* a relaxation of published maximum ratings; rather, it provides some indication of performance in those specialized applications where the risk to the vidicon might be justified.

HIGH-TEMPERATURE OPERATION

Published data for most vidicons lists a maximum recommended faceplate temperature of less than 75°C. A limited sample of typical 7038 vidicons (maximum recommended faceplate temperature of 60°C) was tested from 30 to 90°C. The resultant data, obtained only during short-term high-temperature excursions lasting 30 minutes, indicates that dark current increases with increasing temperature, and that vidicon sensitivity at a constant dark current decreases with increasing temperature. In general, no permanent changes in vidicon characteristics were caused by the high-temperature operation, and temporary changes were consistent from one excursion to another. Resolution was maintained up to 90°C.

In Fig. 1, the value 100 on the relative-target-voltage scale corresponds to a range of 60 to 100 volts for a typical tube; these curves show that target voltage may be decreased to maintain constant dark current as temperature increases.

Figs. 2 through 5 show that there is a greater loss of sensitivity per degree change in temperature at the higher temperatures; at low temperatures, a greater loss of sensitivity per degree change in temperature occurs at the lower dark currents.

This data can be applied to the design of camera systems intended for operation over wide ranges of ambient temperature. For example, a camera may be designed to operate automatically over a temperature range of from 30 to 80°C at a dark current of 0.06 μa. Fig. 1 shows that for this value of dark current at 30°C, the target voltage is 45 to 75 volts. To maintain a dark current of 0.06 μa as temperature increases, the camera must be equipped with a temperature-sensitive device that will reduce target voltage in accordance with the curve of Fig. 1, so that at 80°C the target voltage is about 7 to 12 volts.

Faceplate illumination must also be increased with increasing temperature to provide a constant signal-output current. Fig. 3 shows that at a dark current of 0.06 μa, the faceplate illumination must be increased from 1 ft-candle at approximately 30°C to 20 ft-candles at 80°C to maintain a constant signal-output current of 0.2 μa. This increased faceplate illumination might be provided by an automatic temperature-sensitive iris control.

IMAGE BURN AT HIGH LIGHT LEVELS

Image burn in vidicons has been investigated to determine what levels of illumination can be applied to the faceplate of a vidicon before permanent burns result.

Intensity of image burn is not reduced by removal of the near-infrared or ultraviolet energy from the source. Moreover, image burn is not a function of the electric field or current flow across the photoconductive layer.

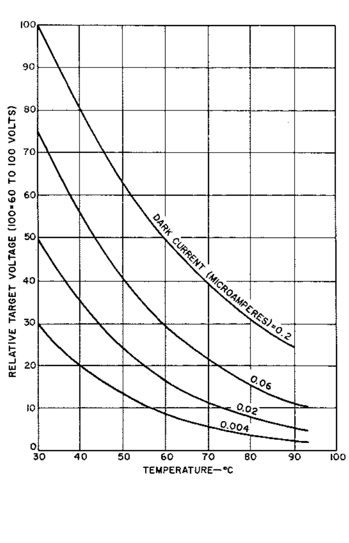
High values of illumination were obtained by focusing an image of the sun onto the faceplate of the vidicon by means of a lens. The illumination level was varied by use of different lens stop openings and, in some cases, by the use of neutral density filters. Table I lists the results.

RESISTANCE TO HIGH PRESSURE

Vidicons were placed separately into a small pressure chamber. Nitrogen gas under high pressure was leaked into the chamber by means of a regulator valve. The gas pressure was increased until the vidicon imploded, at which time the pressure was recorded. Table II lists the results.

The tubes were not held under pressure for any length of time; in all cases, the pressure test for each vidi-

Fig. 1—Signal-output current vs. temperature at various dark currents for typical 7038 vidicon.



GEORGE A. ROBINSON received the B.S. in Electrical Engineering from Iowa State University in 1954. He joined RCA in January, 1955. After completing the Design and Development Training Program, he became a design engineer for flying-spot kinescopes. Since 1957, he has been an applications engineer on vidicon and image orthicon camera tubes. He recently joined the Vidicon Design and Development Group.

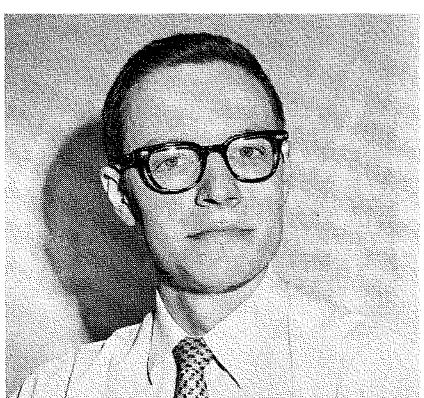


Table I.—Exposure Time for Permanent Burns

Faceplate illumination (ft-c)	Exposure Times: Definite	Probable	Possible	Unlikely
33,200,000	⅓ sec	—	—	—
20,700,000	½ sec	—	—	—
10,300,000	1 sec	—	—	—
1,890,000	12 sec	3 sec	—	—
1,170,000	20 sec	5 sec	1 sec	—
619,000	1 min	12 sec	3 sec	—
292,000	3 min	30 sec	5 sec	—
150,000	8 min	1 min	9 sec	—
103,000	15 min	5 min	12 sec	—
37,000	45 min	20 min	1 min	1 sec
18,900	1½ hr	45 min	5 min	2 sec
9600	—	2 hr	15 min	6 sec
9200	—	2½ hr	20 min	8 sec
6190	—	3 hr	30 min	10 sec
2920	—	—	1 hr	20 sec
1890	—	—	2 hr	30 sec

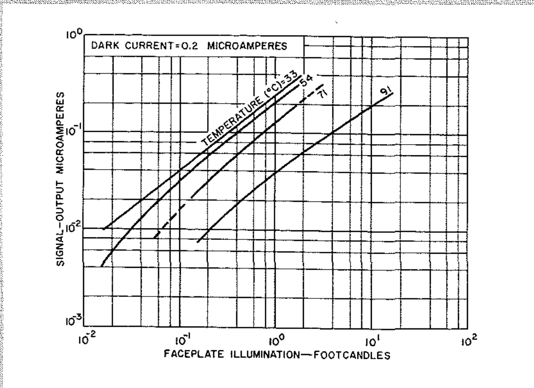


Fig. 2—Signal-output current vs. faceplate illumination; 0.2-μa dark current.

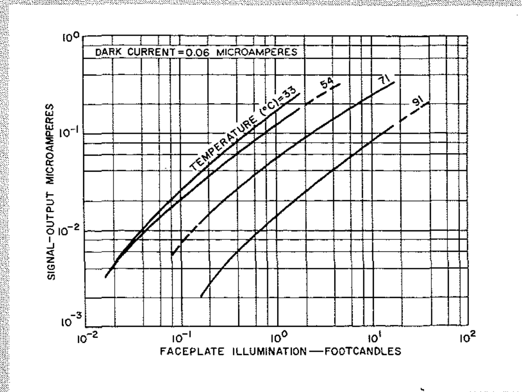


Fig. 3—Signal-output current vs. faceplate illumination; 0.06-μa dark current.

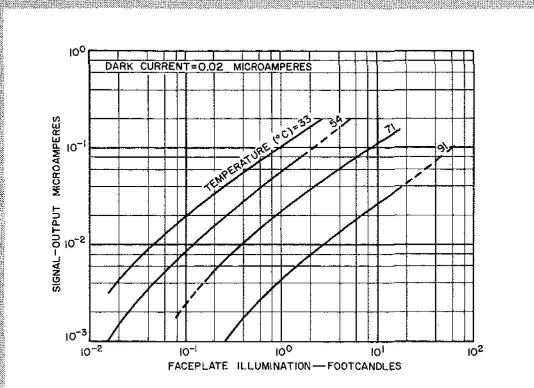


Fig. 4—Signal-output current vs. faceplate illumination; 0.02-μa dark current.

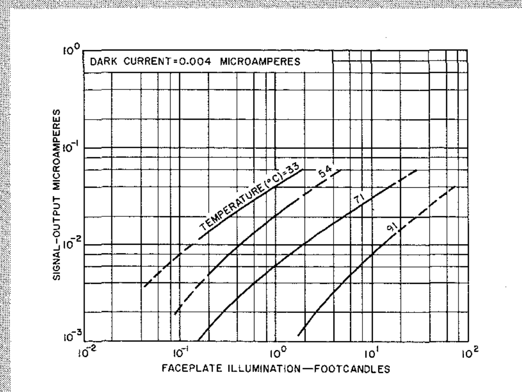


Fig. 5—Signal-output current vs. faceplate illumination; 0.004-μa dark current.

con was performed in less than 10 minutes. Moreover, the tubes were not subjected to any shock or vibration while in the chamber. These conditions should be considered for field applications involving high pressures.

EFFECT OF NUCLEAR RADIATION ON SPECTRAL SENSITIVITY

A type 6198 vidicon was exposed to a total radiation dosage of 10^{15} neutrons/cm^2. The spectral response of the photoconductive layer was unchanged by irradiation; however, the total measured output-signal current was reduced by approximately 34 percent, and the blue sensitivity of the vidicon was reduced as a result of discoloration or browning of the faceplate.

The transmission of the irradiated faceplate coated with a transparent conductive layer (measured with a Weston photronic cell) was 60 percent, as compared with 92 percent for a nonirradiated transparent-conductive-layer-coated faceplate similarly measured. The 35-percent reduction in transmission caused by radiation browning substantially agrees with the total output-signal current drop.

Theoretical output-signal current I for a vidicon is calculated by:

$$I_s = (K\int_0^\infty E_\lambda T_\lambda S_\lambda d_\lambda)^\gamma$$

Where: E_λ = power per unit of wavelength at wavelength λ of a 2870°K tungsten source; T_λ = spectral transmittance at wavelength λ of the transparent faceplate; S_λ = sensitivity at wavelength λ of the photosurface in amperes/watt; γ = gamma value of the vidicon; and K = a constant.

The drop in output-signal current is determined by the ratio of the output-signal current for a normal vidicon and an irradiated vidicon. The expressions were integrated for wavelength between 3600 and 6400 angstroms; values for T_λ are given in Fig. 6.

The current drop is 32 percent, calculated from:

$$\frac{I_{s_2}}{I_{s_1}} = \left(\frac{495.7}{892.6}\right)^{0.65} = 0.68$$

These correlating values show that the loss in signal from the irradiated tube was entirely caused by faceplate browning and not by decreased sensitivity of the photosurface.

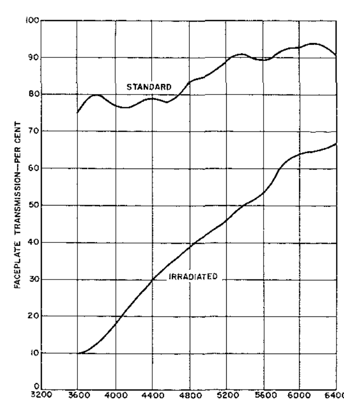
Table II.—Results of High-Pressure Tests

RCA Type	Results
Dev. No. C73484 ½-in., cold seal*	Imploded at 530 psi (36 atm)
Dev. No. C73475 ½-in., rf seal	Did not implode, but faceplate fractured at 950 psi (65 atm)
7038 } 1-in., cold seal†	Imploded at 850 psi (58 atm)
7038 } 1-in., cold seal†	Imploded at 700 psi (48 atm)
7038 } 1-in., cold seal†	Imploded at 680 psi (46 atm)
6326 } 1-in., rf seal	Sound at 950 psi (65 atm)
6326 } 1-in., rf seal	Sound at 950 psi (65 atm)
6326 } 1-in., rf seal	Sound at 1150 psi (78 atm)

* Also would apply to type Dev. No. C74053.

† Should apply also to types 7262-A, 7263-A, 7735-A, 7697, and 2048-A—all having 1-in. cold seals.

Fig. 6—Transmission of 6198 vidicon faceplate vs. wavelength before and after irradiation.

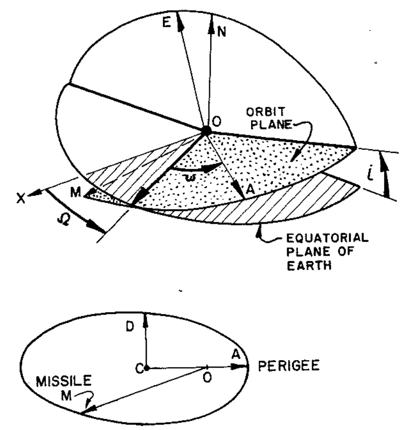


ANGLE-DAMPED DOPPLER TRACKING SYSTEM

by **R. LIEBER and S. SHUCKER**
Missile and Surface Radar Division
DEP, Moorestown, N. J.

This simple ground tracking system is capable of providing highly accurate orbital data in nearly real time. The system tracks orbital or ballistic bodies obeying well-defined laws. The sensor outputs are two angles (or equivalently direction cosines) and rate of change of line-of-sight distance. The data is combined in a computer to give present and future positions of the body. The system is useful for all tracking operations except for powered flight.

Fig. 1—Orbital parameters; a = semimajor axis = AC; e = eccentricity = $[1 - (DC/AC)^2]^{1/2}$; i = inclination angle; ω = argument of perigee; Ω = right ascension of ascending node; τ = time of perigee passage; O = center of earth; OX = direction of vernal equinox.



With the advent of ballistic missiles, satellites, and space vehicles, the tracking problem has changed.

Formerly, the total flight of tracked bodies was powered and under a form of guidance that allowed the tracking station no real *a priori* knowledge of the flight path. Vehicle maneuverability was high and position determination had to be instantaneous; wideband systems were required. Because of motive power limitations in the tracked body, tracking distances were not extreme.

Now, in the missile and space era, the percentage of powered flight to non-powered flight has decreased radically. In the case of a ballistic missile, the powered flight may be only 20 percent of the total flight. With satellite and space vehicles, the powered flight time is insignificant. Yet, the requirement for *tracking distance* has become tremendous—ranges are measured in tens of thousands of miles, as compared to the tens of miles in the old era.

TRACKING PROBLEM SOLUTIONS

Fortunately the two current problems can be compatible. The unpowered flight allows for an analytic problem formulation leading to the use of only narrow-bandwidth information, which produces the tracking distance through the use of compatible receivers and space-vehicle-mounted transmitters. Because of their inherent simplicity (again due to narrow information bandwidth) the space-vehicle-mounted transmitters have acceptable (to space-vehicle designers) weight and power-drain characteristics.

The angle-damped doppler system:

1) takes advantage of *a priori* information to formulate the tracking problem such that all narrow-bandwidth information can be best used;
2) gathers all available beacon-transmitted narrow-bandwidth information for use in the solution to the tracking problem;
3) presents a problem solution, using all of the gathered information, in nearly real time.

COMPUTER EQUATIONS

The outputs of the sensor portion of the angle damped doppler system are range rate $\dot{r}$, azimuth A, and elevation E. These quantities form the computer input.

The sensor outputs are written as functions of the orbital parameters (Fig. 1):

$$\begin{aligned} \dot{r} &= G\,(a, e, i, \omega, \Omega, \tau) \\ A &= H\,(a, e, i, \omega, \Omega, \tau) \qquad (1) \\ E &= I\,(a, e, i, \omega, \Omega, \tau) \end{aligned}$$

Equations 1 are linearized by expanding them in Taylor's series form and retaining only first order terms:

$$\begin{aligned} \Delta\dot{r} &= \frac{\partial G}{\partial a}\,\Delta a + \ldots + \frac{\partial G}{\partial \tau}\,\Delta\tau \\ \Delta A &= \frac{\partial H}{\partial a}\,\Delta a + \ldots + \frac{\partial H}{\partial \tau}\,\Delta\tau \qquad (2) \\ \Delta E &= \frac{\partial I}{\partial a}\,\Delta a + \ldots + \frac{\partial I}{\partial \tau}\,\Delta\tau \end{aligned}$$

Solutions for $\Delta a, \ldots \Delta\tau$ are found by minimizing the weighted sums of squares of the differences between the left and right hand sides of equations 1 and 2. This leads to the normal equations:

$$\begin{bmatrix} A_{11} & \cdots & A_{16} \\ \cdot & & \cdot \\ \cdot & & \cdot \\ \cdot & & \cdot \\ \cdot & & \cdot \\ A_{61} & \cdots & A_{66} \end{bmatrix} \begin{bmatrix} \Delta a \\ \Delta e \\ \Delta i \\ \Delta\omega \\ \Delta\Omega \\ \Delta\tau \end{bmatrix} = \begin{bmatrix} B_1 \\ \circ \\ \circ \\ \circ \\ \circ \\ B_6 \end{bmatrix} \qquad (3)$$

Where: B_1 to B_6 contain the observed values of $\dot{r}$, A, E. The computer solves these equations, as follows:

1) An initial estimate of the orbital elements $a \ldots \tau$ is made.
2) From the initial estimates computed vales, r_c, A_c and E_c are determined (equations 1).
3) At each measurement instant, the terms $\Delta r = r_m - r_c$, etc. are formed (equations 2). Subscript m denotes measured values.
4) The values of the coefficients $A_{11} \cdots$ and $B_1 \cdots$ are computed.
5) The equations 3 are solved for $\Delta a \cdots \Delta\tau$, the corrections to initial estimates of orbital elements.
6) The procedure is repeated until the $\Delta a \cdots \Delta\tau$ corrections are below some desired value. During the repetitive procedure, the angle data is given progressively less weight, finally being used only to damp the computation. The name, *angle-damped doppler system*, derives from this procedure.

Observation of the results of extensive digital simulation show that the computation system is analogous to a linear servo. Drawing on the linear-servo theory, the computation system and dual properties are shown in Fig. 2.

MEASUREMENT SUBSYSTEM

The specification of the measurement subsystem can be carried through many levels of technical detail. One usually starts with a final accuracy specification from the customer and proceeds from that point to define the allowable output errors in the measurement device. Further specification of the system to meet tracking distance and dynamics requirements leads to choice of beacon power, receiver sensitivity, antenna gains and tracking loop configurations. The following deals only with the customer accuracy requirements and the steps taken to translate them into allowable measurement-system output errors.

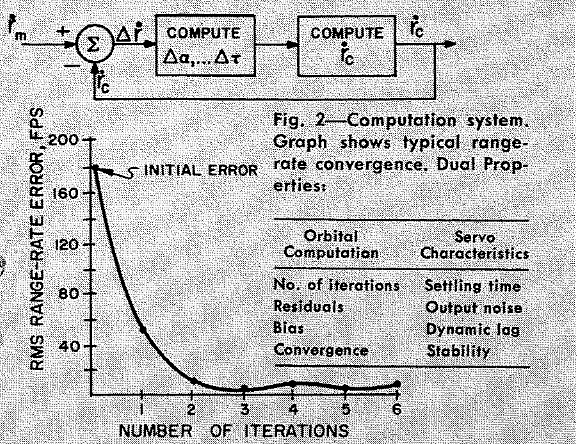


Fig. 2—Computation system. Graph shows typical range-rate convergence. Dual Properties:

Orbital Computation	Servo Characteristics
No. of iterations	Settling time
Residuals	Output noise
Bias	Dynamic lag
Convergence	Stability

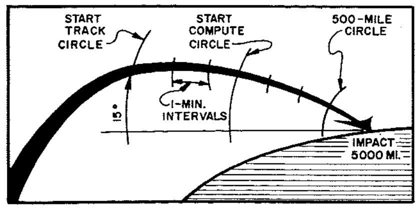


Fig. 3—Target geometry.

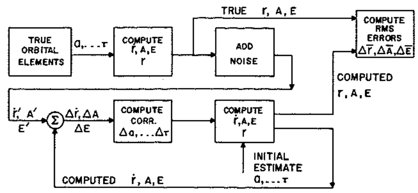


Fig. 4—System simulation.

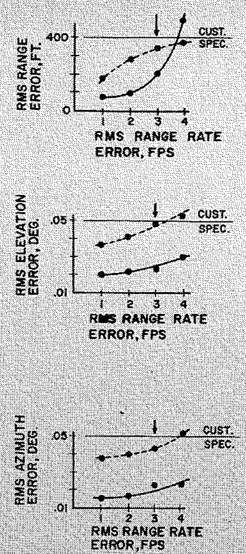


Fig. 5—Simulation results. RMS angular measurement errors: dashed curves, 0.25°; solid curves, 0.1°.

Customer Specification

The customer specification for a given missile tracking application is:

1) Data-taking span limit to be chosen by contractor.
2) System rms error over the data taking span: range $\leq$ 400 feet, azimuth $\leq$ 0.05°, and elevation $\leq$ 0.05°.
3) Output in real time starting at 500-mile slant ranges measured from impact point.
4) Site within 25 miles of impact.
5) ICBM trajectory as given in Fig. 3.
6) Frequency, 215 to 265 Mc.

Derivation of Allowable Data Span

Critical to meeting the customer output requirements is the allowable data-taking span, since the computation is a curve-fitting process; hence, the more data, the better the curve fit. The first part of the investigation is then concerned with the trajectory of the body to be tracked. From Fig. 3, a knowledge of the computation time requirements, and the 500-mile slant-range specification, the lower limit of the data-taking time span can be pinned down. The computation time has previously been determined to be about 3 minutes for thirty data points and 90-percent computation convergence to final values. The 500-mile and three-minute computation time is noted on Fig. 3. To determine the upper limit for data taking, the effects of propagation as related to tracking elevation angles must be considered. A conservative lower limit on the tracking elevation angle from a propagation standpoint is 15°. That is, for a reasonable choice of tracking device, the accuracy of the device will not be changed to a first order by refraction and multipath at elevation angles greater than 15°. The 15° angle is plotted on Fig. 3 and its intersection with the trajectory gives the starting point of the data-taking interval. This interval is then found to be about 3 minutes in extent. To allow for a safety factor in time, a 150-second data span is chosen for simulation purposes, giving a 30-second margin in the design of the real system. This margin can be used for search, tracking, or computation.

Tracking Subsystem Output Requirements

To determine the tracking subsystem output requirements, a band of values for angle and range-rate accuracy is chosen and used in a digital simulation. The simulation (Fig. 4) is carried out in the following steps:

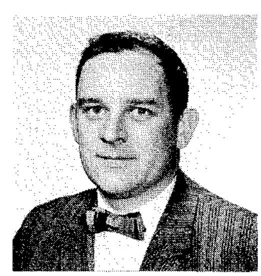
1) A set of orbital parameters is fitted to the customer-specified missile trajectory (Fig. 3).
2) The orbital parameters are converted to values of range rate, azimuth and elevation as seen at the impact point.
3) Noise is added to the values of step two.
4) A set of initial values of orbital elements are chosen that correspond to missile impact approximately 100 miles from the true impact.
5) The noise values of step three, plus the estimated initial elements of step four, are used in the orbital calculation to see how closely the set of true orbital elements of step one can be recovered.
6) The process is carried for three cycles of iterations and the rms range, azimuth, and elevation errors between the computed trajectory and the trajectory of step two are computed (Fig. 5).
7) The curves of step six are used to define the output requirements.

From the curves of Fig. 5 and the customer's specification, the tracking subsystem output requirements are seen to be: range-rate accuracy, $\leq$3 fps; and angle accuracy, $\leq$0.25°.

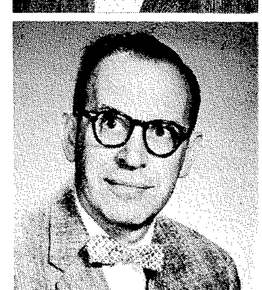
CONCLUSIONS

Excepting the realization of the range rate accuracy, which requires some special attention due to the customer's choice of frequency, the tracking subsystem requirements are modest and lead to very simple instrumentation. Thus, by proper use of *a priori* information and the proper combination of available measurements, quite respectable tracking accuracy can be achieved with unsophisticated devices.

R. LIEBER received his BSME from the University of Miami and his MS from Drexel Institute of Technology. At the Army's Frankford Arsenal from 1950 to 1952, he was responsible for hydraulic circuit development. Joining RCA in 1952, Mr. Lieber contributed to development of the AN/APN-42 subminiaturized pulse radar altimeter and the "Black Cat" low-altitude penetration system. He then became responsible for the integration of the MIT-SPIRE System with the RCA-developed K-band terrain clearance radar. From 1956 to 1958 he undertook functional engineering of inertial navigation systems and self-stabilized missile-seeker systems. Since 1958, Mr. Lieber, as Leader of an Analysis group, is responsible for major portions of DAMP and advanced tracking and guidance systems.



DR. SIDNEY SHUCKER received the BSEE in 1948 from Drexel Institute, and the M.S. in EE in 1949 and the Ph.D. in 1961 from the Universty of Pennsylvania. From 1949 to 1951, he worked on development of radar circuits and instrument servos. Since joining RCA in 1951, he has worked in the fields of servomechanisms and systems engineering.



INDUSTRIAL STANDARDS
...One Road to Profit Improvement

by **D. C. BOWEN, Administrator**
Standards Engineering
IEP, Camden, N. J.

THE DIVERSIFIED LINE of products engineered and manufactured by Industrial Electronic Products has resulted in unique opportunities for profit improvement through the utilization of sound principles of standards engineering. Some of the conditions that have created the need for these principles are *small-lot production, practical limitations on design effort, quality assurance,* and *environmental considerations.*

SMALL-LOT PRODUCTION

With some notable exceptions, most IEP products are manufactured in relatively small quantities — occasionally even in one-of-a-kind lots. While the aggregate cost of all the parts and materials used in a single complex equipment may go into many thousands of dollars, the large majority of parts actually used are inherently low-unit-cost items such as common hardware and simple electronic components. The problem in standardization is to limit unnecessary variety and assure that the more common parts are used in the largest possible number of applications. One of the most effective means for achieving an efficient and economical supply system in production is reflected in the hundreds of items now carried in the Camden Plant alone on a "max-min" basis.

PRACTICAL LIMITATIONS ON DESIGN EFFORT

In mass-produced products such as TV sets or automobiles, large engineering costs for *marginal design*—design to get the last ounce of performance for the least dollars expense — are often rewarded with substantial economies. The same principle applied to the same extremes in the engineering of industrial electronic equipment would rarely pay any dividends. Engineering and drafting time spent in searching for data and documenting the selection of parts in IEP sometimes would cost more than the ultimate price paid for the parts themselves. Standards Engineering provides fully documented data and drawings in readily accessible locations to reduce this repetitive and burdensome problem in product engineering.

QUALITY ASSURANCE

While the sole justification for any standards group is profit improvement through reduced costs, any attempts to reach this goal on a purely dollars-and-cents basis without regard for the irreducible minimum in reliability required would clearly negate the entire program. Standards Engineering is obligated to administer a source approval procedure that will minimize costs and maximize purchasing flexibility without diluting the traditionally high standards of quality and workmanship of the end product.

ENVIRONMENTAL CONSIDERATIONS

In the foregoing discussion of the general nature of the task faced by standards engineers in IEP, much of what has been said would be equally applicable to Defense Electronic Products. DEP, like IEP, must run a production operation that frequently resembles a large job shop. There are the same practical limitations on marginal design effort because of product diversification and the absence of a solid base of mass produced items. Standards for equipment reliability established by the military are as high as any in the industry and are occasionally not even attainable within the present state of the art.

At this point, however, a major differentiation between environmental objectives is worthy of note. Standardization within IEP is greatly facilitated by the fact that the majority of its products are designed for end use in very favorable conditions of ambient temperature and humidity. Resistance to extremes of environment is needed only during that relatively short period of its life span when the product is in storage or in transit to the customer. While this is not the case for all IEP products, it is for most; the net result is actually greater reliability with lower costs in many specific instances.

IEP STANDARDS ENGINEERING

Having sketched the general nature of the IEP standards problem, the balance of this article will be devoted to what has been done to date and how future projects are likely to be oriented.

How It Started

IEP Standards Engineering came into being as an organization in April, 1958. Its charter has always been based on the decision by management that overhead funding (rather than direct charges) is the only practical means for providing financial support. For nearly a year and a half, the total complement of full-time personnel in this operation consisted of the Administrator. Clerical and drafting services were shared with another group. Within the first month of service, proposals were formulated for a long-range extension of services to provide adequate depth and breadth of technical and administrative skills while remaining small enough to insure a high calibre of work performed with a substantial return on the investment.

Organization

An organization chart that also shows the relation between Standards Engineering and other IEP Engineering Services is shown in Fig. 1.

Within Standards Engineering itself, the *Administrator* is responsible for guiding the IEP standardization program; he also serves as permanent chairman of the IEP Standards Committee. With the present personnel alignment, specific working assignments are divided along the following lines: *Administrator,* standards in electrical components; *Mechanical Standards Specialist,* standards on mechanical components, materials, and drafting and design practices; *Standards Analyst,* classified print file, vendor data file, and routine administrative operations. Because the group is small, there is a continual interchange of information and assistance.

Objectives and Methods

The *sole objective* of IEP Standards Engineering is profit improvement. In working towards an eventual solution to a problem in standardization of average complexity, the primary goal is to optimize all of the important factors that contribute to ultimate value. A few of these factors and the relative ease or difficulty of measuring them are:

Purchase Price of Parts or Material. Precise comparisons readily available.

Internal Handling Costs. Includes breakage of fragile parts, cost of inspection, cost of rework prior to assembly, cost of handling rejects, cost of handling in the stockroom. Difficult to arrive at reliable, before-after cost figures.

Assembly Costs. Can usually be estimated with reasonably good accuracy by experienced industrial engineers.

Assembly Rework. Cost of replacing parts or repairs after assembly but before final release by Quality Control. Difficult to evaluate except in "epidemic" cases when cost of a single isolated problem becomes quite appreciable.

Engineering Administrative Costs. Includes cost of preparing new drawings or adding parts to existing drawings, searching print files, and searching for vendor data. These costs are almost impossible to evaluate precisely.

Improvement in Quality. An intangible but important asset.

Cost of Repairs Within Warranty. Records are usually inadequate.

Two typical industrial standards that will eventually result in improved profits through operating economies are illustrated in Tables I and II, compared with the foregoing criteria. While neither of these standards are of such a nature as to give rise to any dramatic or very large reduction in costs, they have been selected to show different modes of accomplishing the same objective.

THE FUTURE—PROFIT IMPROVEMENT

Standards never have been and never will be a panacea for all problems. A judicious application of its principles, however, will serve to promote an increasingly efficient utilization of the material and manpower resources of IEP—as it has already done in many other manufacturing groups within RCA and elsewhere. A handsome payoff in improved profits is now being realized and should show steady future growth.

TABLE I — PLASTIC GROMMETS

Purchase Price of Parts. Standard parts cost 3 times as much per unit as the conventional rubber grommets in typical small lots. Over the long haul, with quantity discounts, the standard part will still cost twice as much as the nonstandard part.

Internal Handling Costs. Significant reduction in variety will come about with fewer requisitions, fewer purchase orders, fewer shipments to inspect and stock, a greater than 50-percent reduction in Max-Min stock and probable future use of blanket purchase orders.

Assembly Costs. These will be down 50-percent, thus almost offsetting added unit cost.

Assembly Rework. Less susceptible to mechanical damage and nearly impossible to work loose to cause need for re-insertion.

Engineering Administrative Costs. The standard part is expected to be suitable in more than 90-percent of grommet applications. All part numbers and data will be available on a single-sheet standard to eliminate much file searching and checking of old drawings.

Improvement in Quality. The standard part is practically immune to most environmental conditions with a much improved life expectancy.

Improvement in Saleability and Customer Satisfaction. Not significant.

Cost of Repairs Within Warranty. Not significant.

TABLE II — STOCK COMPRESSION AND EXTENSION SPRINGS

Purchase Price of Parts. Tooling and set-up charge eliminated entirely for about 1500 line items. Stocked by the manufacturers for off-the-shelf delivery. Aggregate direct savings should eventually exceed 30-percent.

Internal Handling Costs. No appreciable reduction in variety likely, but use of standard, tabulated drawings should lead to use of simplified blanket purchase order system.

Assembly Costs. Not a factor.

Assembly Rework. Minor reduction possible through improved uniformity of product.

Engineering Administrative Costs. Standard part expected to be suitable in more than 90-percent of applications. File searching and preparation of new drawings virtually eliminated except for "specials."

Improvement in Quality. More production continuity at source should lead to better average quality. Less trouble expected from hydrogen embrittlement.

Improvement in Saleability and Customer Satisfaction. Not significant.

Cost of Repairs Within Warranty. Not significant.

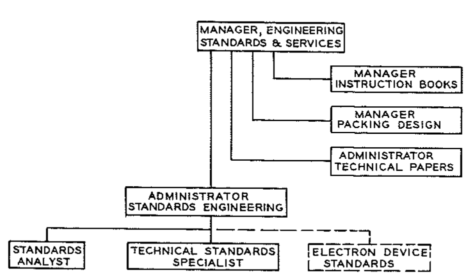


Fig. 1—Members of the IEP Standards Engineering Staff (J. P. Gasslein, left, author D. C. Bowen, second from left, and K. M. Stoll, right) discuss utilization of standard parts in an electromechanical clutch with C. M. Russell (second from right) of the EDP Division. INSET CHART: Organization of IEP Standards Engineering.

D. C. BOWEN received the B.E.E. Degree from Rensselaer Polytechnic Institute in 1948. After some graduate studies in mathematics at R.P.I., he became an instructor in 1948 in the Electrical Engineering Department at the California State Polytechnic College, San Luis Obispo, Calif. From 1951 to 1952 Mr. Bowen, as a Senior Research Engineer with the Convair Guided Missile Division, performed studies in system design parameters and circuit synthesis. In 1952, he joined RCA as Manager of the Electrical Standards Section, Division Standardizing. Mr. Bowen transferred in 1958 to head IEP's Standards Engineering group. He is a senior member of the IRE and member of the Standards Engineers Society. Active in the ASA, EIA and IRE since 1952, he is presently a member of the EIA General Standards Committee and the ASA Sectional Committee for Electronic Components, and is Chairman of both the EIA Departmental Committee on Colors and Numbers and the Symposia Committee, IRE Philadelphia Section.

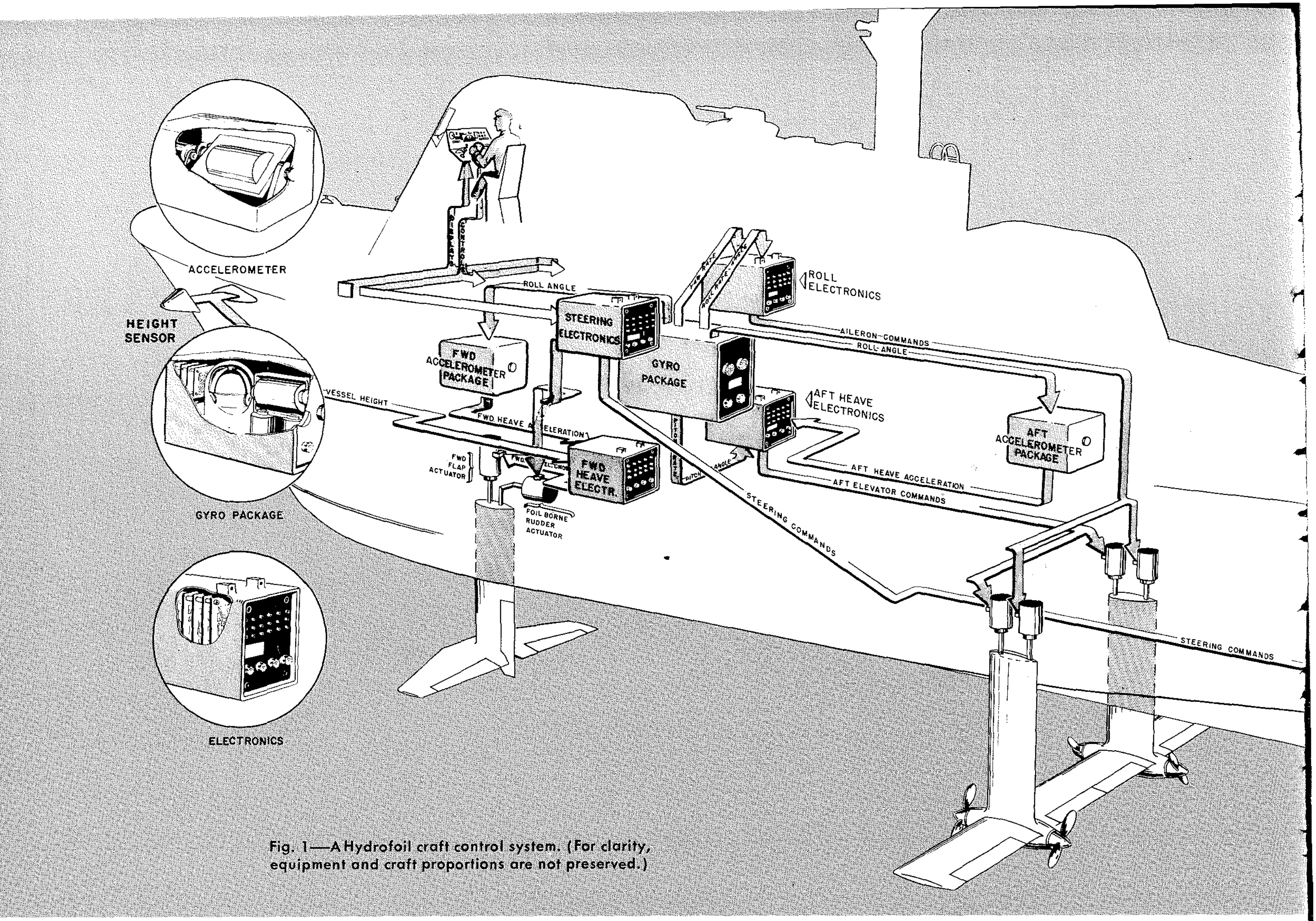


Fig. 1—A Hydrofoil craft control system. (For clarity, equipment and craft proportions are not preserved.)

AUTOMATIC CONTROL FOR HYDROFOIL CRAFT

by **R. C. BLANCHARD and D. WELLINGER**
Aerospace Communications and Controls Division
DEP, Burlington, Mass.

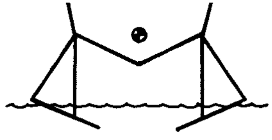
THE CLASSICAL DEFINITION of hydrofoil is: *a plane surface, flat or curved, designed to obtain reaction upon its surfaces from the water through which it moves.* The hydrofoil craft (mounted on struts supported by underwater foils) substantiates the definition by rising clear of the water at high speeds. These foils literally fly in the water, generating enough "lift" to cause the hull to climb from the displacement into a "flight" condition. A hydrofoil craft can also be thought of as a type of conventional boat, since it has a hull and floats safely in water at low speeds or at rest. (See Figs. 1 and 2.)

HYDROFOIL-AEROFOIL COMPARISON

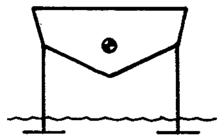
For the past half century, since the Wright brothers first flight in an aerofoil equipped machine, the basic concept of the lift producing hydrofoil has been understood and sporadically exploited. Indeed, the principles describing the generation of lift forces on a body traveling in a fluid medium are the same for the aerofoil and hydrofoil. It is the difference in density of the mediums, a ratio of approximately 800:1 for water and air, that has resulted in the very significant practical differences that separate the technologies of hydrofoil seacraft and aerofoil craft.

The area of a foil to produce a given lift force during water travel is about 800 times smaller than that required for the same lift while traveling through air, assuming similar conditions of speed and incidence angles. Hence, the linear dimensions of a hydrofoil configuration designed to support a conventional displacement hull are much smaller than the dimensions of such a hull. In contrasting aircraft design, the aerofoil or wing dimensions are generally of the order of the fuselage dimension. The ratios of the areas of aerofoils and hydrofoils do not differ as greatly in practice as the density ratios indicate, since typical operating speeds of aerofoils are substantially greater than those of hydrofoils.

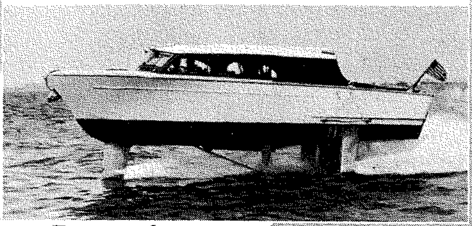
The ability to lift the hull of a seacraft clear of the water at high speeds, leaving only the comparatively small lifting foils and supporting struts underwater, has the obvious advantage of eliminating the friction and wave-drag of the hull. These drag forces, also proportional to the water density, impose a severe power penalty on a displacement-type craft whenever its top speed is increased. In addition, when the hull is kept clear of green water, the wild pitching and heaving motions resulting from forces normally generated by the action of waves on a buoyant hull are absent. Although the waves do have some influence through forces imposed on the foils and struts,



(a) AREA STABILIZED OR SURFACE PIERCING FOIL



(b) INCIDENCE - CONTROLLED OR FULLY SUBMERGED FOIL



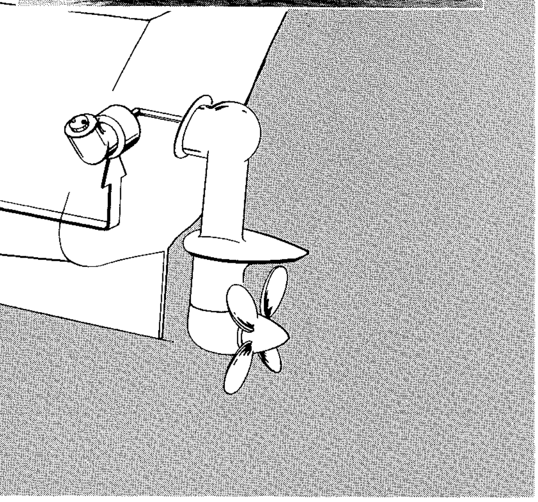


Fig. 2—(Inset at left) At top, two types of hydrofoil craft. In the photo, a U.S. Navy experimental 29-foot, 5-ton hydrofoil craft, the *Sea Legs*. It is auto-pilot controlled, and variable-incidence type.

one may expect a substantially improved ride in a hydrofoil craft compared to that of a displacement vessel.

TYPES OF HYDROFOIL CRAFT

Of the hydrofoil craft constructed during the past half century, the great majority have been the *area-stabilized*, or surface-piercing, types. Such craft are stabilized in heave (vertical displacement) by hydrofoils that partially extend above the surface by virtue of a substantial dihedral angle (Fig. 2a). Thus, the effective lifting area of such a foil is decreased when the craft rises out of the water, tending to lower the craft again. Conversely, a downward heave motion results in a greater area of foil submergence, with a subsequent increase in lift tending to return the craft to the higher position. Thus the inherent geometry of the foil configuration in an area-stabilized craft supplies heave stability. Similarly, roll stability is realized through roll moments produced by the same set of foils.

Another major class of hydrofoil craft, the *incidence-controlled*, or fully submerged, type, has had substantially fewer applications in the past half-century, but is currently enjoying warranted attention. The incidence-controlled hydrofoil resembles a wing without a significant dihedral, sometimes mildly swept back, but always operating completely submerged (Fig. 2b). Such a foil possesses no inherent heave stabilization; i.e., there is no significant change in lift with a change in depth. Accordingly, it is necessary to provide stability by adjusting the lift, either through variations of the angle of incidence of a fully rotatable foil, or through variations of the angle of a trailing-edge flap attached to a fixed foil.

At typical speeds (25 to 60 knots) of present-day incidence-controlled hydrofoil craft, the dynamic forces are such that a human operator cannot manually control the incidence of the foils well enough to insure a smooth ride (without broaching the foils or slapping of the hull). Consequently, automatic control systems must be provided. For this reason, the incidence-controlled craft has not been utilized as much as the area-stabilized type. Indeed, it has been only in the last fifteen years that practical feedback design techniques have been evolved to permit the analysis of the dynamic problems of such control systems.

EFFECT OF CONTROL SYSTEMS ON HYDROFOIL CRAFT PERFORMANCE

It may be asked why a control system and rotatable foil should replace the fixed geometry, area-stabilized foil design.

The answer to this lies in the wave-generated forces mentioned earlier. Associated with every wave are water-particle velocities which are maximum at the surface of the water and decrease *exponentially* with depth.[1] As the hydrofoil passes through waves, water-particle velocities give rise to perturbations in the hydrofoil lift at the frequency-of-encounter of the waves. The area-stabilized foil, having fixed geometry and an angle-of-incidence affected only by craft pitch motion, is buffeted by these wave forces with commensurate effect on the craft ride. Although careful foil design can minimize such effects for a given sea state, a wide variety of sea states are encountered in practice, and optimization over the entire spectrum of wave encounter is not possible. Thus, the area-stabilized commercial hydrofoil craft have been confined to operation in inland lakes, rivers, or coastal waterways.

On the other hand, the independent control of lift possible with the incidence-controlled hydrofoil can be used to counter wave disturbances in rough waters. The excellent sea-keeping ability (i.e., sustaining speed and a steady platform in rough water) afforded by incidence-controlled hydrofoils has been demonstrated in the U.S. Navy's experimental 29-foot, 5-ton hydrofoil craft, *Sea Legs*, shown in Fig. 2. The Navy considers this craft the most successful fully-submerged hydrofoil craft built to date.[2] The work on this craft was accomplished under a U.S. Navy Bureau of Ships contract to Gibbs & Cox, Inc., of New York, and that portion concerned with dynamic analysis and control system design and development was carried out by the Flight Control Laboratory of M.I.T. Near the final phase of this program the hydrofoil control system group joined RCA, continuing to completion necessary follow-up during the sea-trial phase.

The final report submitted by Gibbs & Cox on the operating experiences of the craft[3] stated that "The craft has, on at least one occasion, operated satisfactorily in ocean *swells* of 10 feet or better" (wave height is always measured from trough to crest). For a 29-foot craft designed to cope with waves 3 to 4 feet in height, this represents an outstanding performance.

The potential of fully-submerged foil craft for many areas of naval operation has been reaffirmed by the U.S. Navy's recent contract award for a fully-submerged hydrofoil patrol craft for use in anti-submarine warfare.

OPERATIONAL CONSIDERATIONS IN HYDROFOIL CONTROL SYSTEM DESIGN

The vast experience gained in the design of aircraft control systems is useful in the design and analysis of hydrofoil control systems; however, there are areas of hydrofoil control system design where this knowledge is *not* applicable. An example is the altitude control of the craft. Aircraft altitude-control systems are designed to hold deviations within limits measured in tens or even hundreds of feet; in hydrofoil craft, it is critically necessary that "altitudes" be maintained to within *a fraction of a foot*. In addition, this accuracy must be maintained in the presence of cyclic heave disturbances representing lift perturbations equal to a sizeable fraction of the weight of the craft.

Another important factor in the design of a hydrofoil control system is the difference (due to waves) in the immersion of the fore and aft struts. This can

DIRECTION OF WAVE MOTION

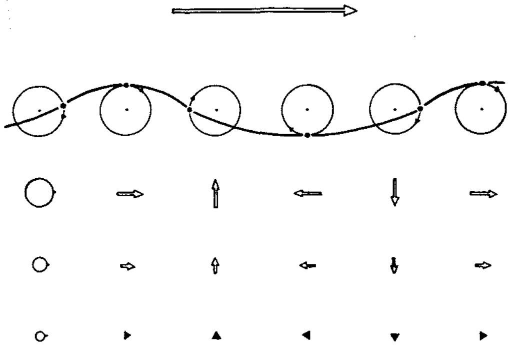


Fig. 3 — Representation of wave motion by curtate cycloid.

result in a severe cyclic change in the dynamic stability of the craft in yaw.

There are two major regimes in which a hydrofoil craft is designed to operate. The first is found in seas where wave heights are *smaller* than the effective strut length—i.e., the vertical clearance between the lowest point on the hull and the foils. Clearly, under such conditions it is geometrically possible to constrain the craft to cruise, foil-borne, on a level line while the wave disturbed surface passes beneath the hull; the foils remain always fully-submerged. This procedure is termed *platforming.*

In contrast to the platforming condition, the other typical operating regime is found in wave height *greater* than the effective strut length. Under these conditions, it is necessary that the craft partially follow the wave contours as they are encountered to prevent broaching of the foils or slapping of the hull. This condition is termed *contouring*. The ideal total craft heave motion for this purpose is equal to the difference between wave height and effective strut length. Under such conditions, forward speed cannot be increased without increasing the discomfort to personnel, since for a fixed heave displacement, heave acceleration increases with the square of wave-encounter frequency, or roughly with the square of speed. Thus, even though peak heave accelerations of 1 g or greater are capable of being produced by controlled foils, passenger comfort requires that vertical accelerations be limited to the order of 0.1 to 0.3 g. One must remember that although accelerations of several g's are not uncommon in military aircraft, these accelerations are not cyclic in nature, while a hydrofoil craft traveling in the contouring regime is being subjected to peak accelerations at the wave encounter frequency, a condition that can lead to severe physical discomfort for typical exposure time durations.

PROPERTIES OF WAVES AND WAVE-INDUCED FORCES

To understand the problem of automatically controlling the hydrofoil, it is desirable to consider the origin of the wave-induced, cyclic lift forces.

For this purpose, we shall consider a train of ocean waves at a point well removed from the source in order to permit the study of a fairly pure wave train. Under these conditions, the wave shape is represented by the curtate cycloid shown in Fig. 3. The small arrows on this figure indicate the velocity of a *water particle* influenced by wave motion. At the crest of a wave, the particle moves in the direction of the wave propagation and, at a trough, counter to the direction of wave propagation; but in all cases, for typical wave conditions, particle velocity is much smaller than wave-propagation velocity. The direction of particle velocity on the front and back face of a wave is perpendicular to wave-propagation velocity. Water particle paths may be considered circles near the surface of water whose total depth is large compared with a wave length. The particle motion, however, dies away rapidly with increasing depth, and the magnitude of particle velocity is described by:

$$V_{om} = \frac{\pi HC}{\lambda} \exp\left(-\frac{2\pi d}{\lambda}\right)$$

$$C = \sqrt{\frac{g\lambda}{2\pi}}$$

Where: V_{om} = particle velocity due to orbital motion, H = wave height (trough to crest), λ = wave length, d = depth below mean water level, C = velocity of wave propagation, and g = acceleration of gravity.

Considering, now, a foil moving through wave-disturbed water at a minimum depth greater than the chord length of the foil, the generated lift of such a foil is perturbed by the particle orbit velocity in two ways. First, at a point below the back or front face of a wave, the orbital velocity vector appears perpendicular to the foil's velocity vector with the net result that the angle of attack of the foil is altered as follows:

$$\Delta \alpha = \frac{\pm V_{om}}{V_c}$$

Where: $\Delta \alpha$ = change in angle-of-attack and V_c = craft velocity. This expression is an approximation, but a good one because, in general, V_{om} is much smaller than V_c.

Second, when the foil is located at a point beneath a crest or trough of a wave, there is an effective increase or decrease in relative velocity due to orbital motion, with a consequent lift-force perturbation. However, since V_{om} is usually much smaller than V_c, lift perturbations due to this effect are considerably smaller than those due to the change in angle of attack mentioned above.

When a foil approaches the free surface more closely than one chord-length, a loss of lift results; this may be thought of as a manifestation of the distortion of the fluid-flow field above the foil. Appearing in the ocean surface above the foil is a hump traveling with the foil and resulting in a loss of energy through the surface wave generated by this phenomenon. This effect is quite important in the consideration of surface-piercing foil dynamics, but is of less concern for most operating regimes of a fully-submerged foil.

FUNCTIONAL DESCRIPTION OF A HYDROFOIL CONTROL SYSTEM

The orbital motion-induced lift perturbations discussed in the previous section may be effectively countered by a suitable variation of flap deflection (or foil incidence change for a fully rotatable foil). It is the primary responsibility of the control system to generate such proper inputs to the flap that the craft *platforms* for smaller waves and *contours* smoothly as increasing amplitudes of waves require it. The foil and control system configurations of Fig. 1 are examples of how this is accomplished.

Consider, first, the means by which the control system produces lift forces and moments on the craft. In Fig. 1, control-system forward-heave forces are produced by two hydraulically actuated trailing-edge flaps attached to a fixed foil on either side of the forward-center strut. Heave forces aft are generated similarly by the flaps on the rear foils. Obviously, impressive pitching moments may also be generated by motion of these fore and aft control surfaces.

Changes in yaw forces and steering are accomplished through bow rudder-action caused by a flap affixed at the trailing edge of the forward strut, with the struts contributing significant side forces and moments.

Rolling moments are supplied by differential motions of the trailing edge flaps aft that have already been mentioned as producing aft heave forces.

The control system required to command suitable responses for these control surfaces is logically divided into two areas: 1) *longitudinal control system,* which controls craft response in heave and pitch through deflection of both forward and aft flaps; and 2) *lateral control system,* which controls craft response in roll through differential actuation of the aft flaps.

The longitudinal control system shown in Fig. 1 may be subdivided into two portions with functions as follows: 1) The *forward logitudinal control system.* It is the duty of this subsystem to counteract wave-induced forces at the forward foil and to respond to flying-height changes demanded by the helmsman or required for contouring large waves. 2) The *aft longitudinal control system.* It is required of this subsystem that the wave induced forces at the aft foil be counteracted and that pitch attitude changes demanded by the helmsman or required for contouring large waves be produced.

The Take-off

The drag of a hydrofoil craft is greatest immediately prior to lifting the hull clear of the water. In order to minimize drag and ease power requirements, and to facilitate take-off in rough water, the pitch attitude of the craft should be adjustable. The desired pitch attitude varies primarily with speed; in practice, it is a compromise between the attitude that will keep the flaps in approximately neutral position and the allowable attitude dictated by craft geometry and sea state. A *pitch-trim* computer provides the information to the control system.

Platforming

The primary sensor for measurements of foil lift perturbations of both fore and aft foils due to wave action is an accelerometer. An approximate integration of the output of this sensor is used to produce a feedback quantity that is, predominantly, a measure of heave velocity. Flap deflections are commanded accordingly to maintain smooth platforming where wave heights permit.

With this loop alone closed around either the fore or aft foil, however, minute heave velocities could exist which would result in an inexorable drift of the foils in heave causing, eventually, broaching of foils or crashing of the hull. Additional feedback for long-term correction is required to maintain a suitable average height and this is provided in the forward longitudinal system by a height sensor. Considerable effort has been expended on the development of equipment that would dependably perform this function.

The most successful technique to date has been the use of ultrasonics in a transmitter-receiver package. Such a device is placed high on the prow of the ship and is thus immune to damage by floating debris. The sensor itself may be subject, occasionally, to spurious outputs from heavy spray or lost signal, but since these effects are short-term, the sensor output can be processed so that the control system substantially ignores these effects.

With the forward and aft foils now provided with the ability to counteract wave disturbances through their respective accelerometer outputs and the forward foil controlled on a long-term basis by the height-sensor output, it remains to provide a similar long-term sense of heave displacement for the aft foil. This is most easily and economically accomplished by using a pitch angle gyro output. The result of such feedback is to constrain pitch attitude constant on a long term basis. Consequently, in the heave direction, the aft foil will play "follow-the-leader" with the forward foil.

Contouring

When larger waves are encountered, height sensor information is processed in the *sea-state* computer to provide control system parameter adjustments with changes in sea state, achieving contouring of proper amplitude and phasing.

Lateral Control System

The primary sensor for measurement of deviations in roll is a gyro giving roll-angle output (see Fig. 1). Use of this feedback enables differential commands to the aft foils which keep the craft level in either straight flight or flat turns.

It is possible to include provisions in the control system for executing banked turns by using yaw-rate feedback. However, in moderate to heavy seas, banked turns are not admissible if wave-slapping against the hull and broaching of the outboard foil tip is to be avoided. When banked turns are employed in the system, the heave accelerometers of the longitudinal system should be roll-stabilized. This feature prevents the partial sensing of lateral accelerations by the heave accelerometers when the craft is in banked turns.

CONCLUSION

A hydrofoil control system employs gyros, accelerometers, and a sonic height sensor to detect motions of the hydrofoil craft. Sensor signals are filtered, modified, and combined to produce proper commands to the foil flaps. Such a system is necessary for controlling a fully submerged (incidence-controlled) foil craft. The excellent sea-keeping abilities of fully-submerged foil craft make them ideally suited for "rough-water" duty.

High-speed hydrofoil craft (speeds greater than 60 knots) require automatically controlled variable-incidence foils. In the future, an increasing number of these craft will appear in both commercial and military uses. Safety, reliability, ease of operation and maintenance, and low cost of the control system are keys to the degree to which the use of fully-submerged hydrofoil craft will expand.

BIBLIOGRAPHY

1. R. C. H. Russell and D. H. MacMillan, *Waves and Tides,* Philosophical Library, New York (1953).
2. *Hydrofoil Development* Committee on Science and Astronautics, U. S. House of Representatives, May 23, 1960.
3. L. E. Sutton and P. E. Kingston, *Five-Ton, Autopilot-Stabilized Hydrofoil Research Craft; Structural Details and Summary of Operations and Revisions,* Gibbs & Cox, Inc., New York (1958).

R. C. BLANCHARD received his BSME and MSME from Massachusetts Institute of Technology in 1951 and 1953 respective, with emphasis on servomechanism and feedback systems. Between 1951 and 1954, he was a Research Assistant and Staff Engineer at the Dynamic Analysis and Control Laboratory, M.I.T., and was concerned with missile autopilot simulation and an improved torpedo control system simulation. Both of these programs involved the tie-in between the actual system physical components and a simulation facility. From 1954 to 1956, Mr. Blanchard, as a member of the U.S. Army, was stationed at Frankford Arsenal, Philadelphia where he assisted in the development of a hydraulic power drive for an anti-aircraft weapon. After joining RCA in 1956, he was engaged in system design problems of an airborne fire-control system, advanced AICBM concepts, and satellite rendezvous simulation. He is currently conducting analysis and simulation on hydrofoil control systems for 100-ton and 300-ton craft.

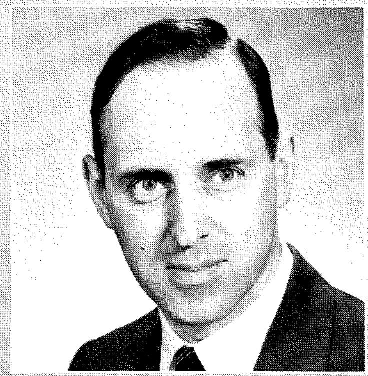
D. WELLINGER received his A.B. in Mathematics from Boston University in 1945, and his M.A. degree in Mathematical Physics and Statistics in the same year. After teaching Mathematics, Physics, and Astronomy for three years at various colleges, he joined Harvard University Laboratory for Social Relations where he did mathematical-model research in the psychology of learning. In 1950, he returned to teaching Mathematics at the University of Connecticut. In 1952, he moved to M.I.T. where he was instrumental in the design of a roll-control system for the Navy's hydrofoil craft *Sea Legs.* He also participated in the dynamic analysis of a missile guidance and control system, and in the correlation of flight-test data. He joined RCA in 1955, and has been engaged in the systems, weapons, and operational analyses of an interceptor fire-control system; and in the analysis of electronic ground environment systems for AICBM. He is currently engaged in system studies associated with antisubmarine warfare and hydrofoil control systems. He is a member of the American Society of Naval Engineers and the American Mathematical Society, and has authored several papers.

DIGITAL COMPUTERS IN ENGINEERING

. . . Powerful New Tools

$$\ddot{\vec{r}} = \frac{\vec{T}-\vec{D}}{m} - g\frac{a^2\vec{R}}{R^3} - 2\omega \times \vec{R}$$

$$g(\mu) = K\int_0^1 (1-r^2)^p J_0$$



DR. G. GRAHAM MURRAY received his B.A. in Electronic Physics in 1944, the M.A. in Mathematics in 1948, and the Ph.D. in Mathematics in 1951 from Harvard University. As a U. S. Naval Officer, he studied radar at Harvard, M.I.T., and the Bell Telephone Lab-

The digital computer offers much to engineers that has only begun to be realized—solving "unsolvable" mathematical problems, allowing cost-saving system simulation with mathematical models, and saving time by mechanizing routine, repetitive engineering tasks. Dr. Murray here discusses computers as engineering tools, illustrating with some applications within DEP engineering. Elsewhere in this issue, Messrs. Lane and Palmer of IEP describe a specific application in more detail—automated wiring design and its implications in mechanizing more of the design process. The economics of computer utilization and their expanding capabilities suggest that engineers should explore their use when a problem or procedure—numeric or non-numeric—lends itself to mechanization.

by **Dr. G. G. MURRAY, Mgr.**

Digital Systems, Missile and Surface Radar Division, DEP, Moorestown, N. J.

THE DIGITAL COMPUTER's meteoric rise to prominence during the past decade has attracted wide interest in its potential applications—from weather prediction to translating foreign languages. Unfortunately, engineers—members of the profession responsible for the design of these machines—*have not yet* applied computers to their everyday work as successfully and dramatically as other groups, for example businessmen.

Many engineering design problems are becoming so complex, however, that they can be handled effectively only by a digital computer. Simulation of a complete system, such as an antiaircraft missile, can lead to an optimum design where there are important criteria, such as miss distance, influenced by many variables. Although engineering requires insight and ingenuity, there are many occasions when the desired solution or design can be obtained by routine procedures and computations. Alertness in investigating the feasibility of machine-processing may simultaneously relieve the engineer of a tedious chore and expedite the project.

Examples of applications of digital computers will be presented here. These are only indicative, because the potential areas of application are almost unlimited and await discovery and exploitation by imaginative engineers.

EARLY APPLICATION OF COMPUTERS

During World War II, the National Defense Research Council received an urgent request to help expedite solutions to ballistics problems at Aberdeen Proving Ground. The large volume of computations required to prepare standard ballistics tables for artillery pieces was overwhelming the available facilities. After study, the council recommended that research and development be initiated on an electronic digital computer—a bold step, since such a machine had never before been constructed.

The University of Pennsylvania's Moore School received a contract and, after overcoming many obstacles, placed in operation in 1945 the ENIAC (Electronic Numerical Integrator and Computer). The soundness of its design was subsequently proven during its distinguished service at Aberdeen calculating trajectories.

Among the outstanding consultants on this project was the mathematician, John von Neumann, of Princeton University's Institute for Advanced Study. In the course of his work, he made many contributions to the theory of logical design of computers. One fundamental concept was the stored program, which greatly increased the digital computer's flexibility and power.

Under von Neumann's stimulus, the computer art surged forward. Soon there was designed and placed in operation at Princeton a new and more powerful electronic digital computer, the IAS machine, which was to become the most copied machine in the world. As engineers and scientists in the nation's laboratories discovered the unique ability of the high-speed, automatic computer to solve difficult problems, many computer projects were initiated.

COMPUTERS IN INDUSTRY

With demand continuing to grow, industry entered the field of computer design and manufacture. Faster and more powerful machines were developed. At the same time, cost per unit computation began to decrease so that the use of machines became economically feasible on typical engineering projects.

Some idea of the diversity of current computer applications can be seen in the following list: trajectories, orbits, aerooratories. From 1951 to 1955, he was a member of the senior staff at the Applied Physics Laboratory, Johns Hopkins University, engaged in systems studies on Terrier and TALOS Missiles relating to guidance, homers, and fuses. Joining RCA's Missile and Surface Radar Division in 1955, he participated in the systems design of computers for the TALOS Missile System, and in establishing the transmission and transformations of data throughout the system. Subsequently, Dr. Murray coordinated a design study for the Signal Corps of a real-time missile tracking and computational facility to control and collect data from all sensors at White Sands Proving Ground. Dr. Murray became leader of the Digital Systems Group at its inception in early 1958, and was appointed Manager in 1959. Dr. Murray's activity has been responsible for the systems engineering of data-processing equipment on the BMEWS Project. Other programs now in process include the processing of satellite tracking data, intelligence data handling, and advanced computer designs for military operation centers.

dynamics, propulsion, guidance, error analysis, heat transfer, electrical networks, communications, structures, atomic physics, power spectra, scheduling, servos, statistics, data reduction, weather prediction, weapon systems, product design, inventory control and cable routing.

Many RCA divisions have met the needs of the engineering staff for computational help by installing digital computers. Others have made use of the BIZMAC computer facility in the Camden complex or the computer operated in the Mathematical Services Group at Princeton for the benefit of the RCA Laboratories as well as other divisions. But the continuing addition of new computers to the RCA family[3], which now includes the 110, 301, 501, and 601 models, will provide even greater opportunities in the future for RCA engineers to use machines.

In turning to digital computers, RCA engineers are in step with their counterparts throughout industry and government. Factors influencing the demand for automatic computation include the increasing complexity of engineering problems, the pressure for shorter development cycles, and the desire to reduce costs. Each of these will be discussed briefly.

ENGINEERING USE OF COMPUTERS

Engineering has become more complex and sophisticated because of the rapidity with which new phenomena and discoveries in basic science are being exploited in both the commercial and military markets. Since equipments in development now border on the state of the art, proper performance can be assured only through extensive engineering calculations. Simulation, the science of predicting equipment behavior by means of mathematical models, has advanced rapidly. The alternative to computation is experimentation with hardware — usually prohibitively expensive.

As an example, without automatic computation, it required nearly 1,000 test flights to prove out the design of the German V-2 rocket. Today, in contrast, only a handful of firings, perhaps 25, are conducted during the development of much more complex missiles, such as TALOS and ATLAS. Digital computers are employed to carry out the equivalent of many thousands of flights to test system performance.

Faster Completion of Systems

Another factor favoring digital computation is the pressure to develop and deliver systems faster. Because of the rapid pace of new advances, equipment is often obsolete upon delivery. Since it has been shown that digital simulation can uncover deficiencies in advance of manufacture, a premium is placed upon engineering computations to guarantee that months of field testing and modifications are not required. For example, in developing a guided missile, a mathematical model of system operation can be established which makes it possible to predict performance for a wide selection of targets, maneuvers, signal-to-noise ratios, sensor accuracies, sampling rates, and relative velocities. If actual tests were conducted, system performance might not be known for years.

Cost Reduction

Cost reduction can also be achieved through simulation. Expensive experimentation can be held to a minimum, flaws noted in advance, and program duration shortened. Perhaps the most important saving lies in more efficient utilization of engineers through removing routine calculations from assignments. Better designs can be achieved sooner and more economically by machine computation, the engineer setting up the problem and the machine solving it. In this regard, H. S. Miller of the Princeton Laboratory recently carried out the analysis of a three-stage tunnel-diode amplifier using a computer to find the total switching delay as a function of various parameters[1]. As this application shows, digital computers can be valuable tools not only in the solution of extremely large and complex problems, but also in applications requiring straightforward computations. In the latter, computers often use their high speed to advantage in running through numerous cases to find an optimum.

SOME COMPUTER APPLICATIONS IN DEP ENGINEERING

As familiarity with digital computation increases, engineers will no doubt discover many new applications. Some idea of the possibilities can be obtained by examining the following uses to which computers have been put on projects in DEP.

Rocket Impact Prediction

A study was conducted for the White Sands Proving Ground on methods of predicting the impact point of a rocket. The basic equation to be mechanized in the impact predictor is:

$$\ddot{\vec{r}} = \frac{\vec{T} - \vec{D}}{m} - \frac{g a^2 \vec{R}}{R^3} - 2\omega \times \vec{R} - \vec{\omega} \times (\vec{\omega} \times \vec{R})$$

Where: $\vec{r}$ is the vector from the launch point to the rocket, $\vec{T} - \vec{D}$ is thrust minus drag, m is mass, g is gravitational acceleration, a is the radius of the earth, $\vec{R}$ is the vector from the earth's center to the rocket, and $\vec{\omega}$ is the vector rotational velocity of the earth on its axis.

In a rocket firing, thrust termination is controlled by a signal from the ground safety station if the impact point computation predicts that the missile may soon leave the range confines. In order to carry out a realtime solution of the above equation ten times a second, a prohibitively large digital computer would have been required.

An analysis was made to see whether a simplified approach was possible[2]. The method finally arrived at was to assume a flat-earth, free-flight solution, and then to introduce corrections or perturbations to account for each of the four terms on the right hand side of the above equation. These are, respectively, drag, spherical-earth gravitation, coriolis force, and centrifugal acceleration. Simulation on a high-speed digital computer showed that the simplified approach agreed with the step-by-step numerical integration of the basic equation to within 0.5 miles, yet permitted a 200:1 reduction in computational steps and also a reduction in computer size.

Radar Antenna Patterns

An important radar design problem is to obtain a desired antenna radiation pattern by selection of the reflector and feed systems. The specification usually calls out a certain gain, beam width (at the half-power points), maximum side lobe level, and other characteristics. Because of the high costs and delay which would attend an experimental approach, antenna designers depend heavily on theoretical models.

For an antenna with a circular radiating aperture, the basic equation giving the far-field radiation pattern is:

$$g(\mu) = K \int_0^1 (1 - r^2)^p J_0 (\mu r) \, r dr$$

Where μ is a normalized parameter closely related to the angular distance off the normal to the antenna; K and p are constants; r is the variable of integration; J_0 is the Bessel function of order zero; and $g(\mu)$ is the square root of radiated power in the direction μ. The function $(1 - r^2)^p$ is the aperture field distribution across the face of the antenna, r being the normalized radial distance from aperture center. By varying p, the designer can adjust the amount of illumination on different parts of the reflector and hence the far-field radiation pattern.

The Moorestown Microwave Antenna Activity has verified that there is excellent agreement between the pattern predicted by this and measurements on completed antenna systems. Furthermore, although it would require from six to nine months to compute $g(\mu)$ by hand for all cases of interest, the same computations have been made in a half hour on the digital computer in the Moorestown Computation and Simulation Facility. This is but one of many radar design problems which have been successfully solved by simulation.

Wire and Cable Routing

A program was written for the BIZMAC computer in 1958 to route wires and cables within cabinets of the BMEWS equipment. The objectives in preparing this computer program were to relieve valuable manpower of routine tasks, to realize savings in cost and time, and to reduce the number of errors. Initial study showed that costs would be lower using the automated method of routing provided at least thirteen standard "eight-in-one" BMEWS cabinets (each with approximately 1,000 wires) were processed in this manner.

As the name implies, the eight-in-one cabinet contains eight racks of equipment in one large frame. Several chassis, in turn are mounted on a rack. Through the center runs a removable harness panel to interconnect chassis within a cabinet and one cabinet with another. This panel contains 16 terminal boards which are identified by zones. Furthermore, each terminal board consists of 30 *modulocs*, each with a capacity for eight wire terminals.

A group of subprograms was prepared to carry out the interconnecting and routing of wires and cables subject to rules established by engineers: 1) The *input edit* routines were designed to check input fields for errors, to sense for control codes, and to batch all connections with common header information. 2) The *cable entry assignment* program called for assigning all wires within a designated cable type between two or more cabinets. 3) The *internal assignment* completed the connections between internal points carrying the same signal and specified the vertical and horizontal wire routes. 4) An *output edit* routine refined the data and prepared it for the high speed printer and wire list format.

These programs were used successfully in 1958, and after initial experience improvements were made in certain areas, such as processing Engineering Change Notices and preparing special rework wire lists. This project has demonstrated the feasibility of automating wiring and cabling, and at present these general techniques are being applied on other projects. [*For details, see Lane and Palmer, elsewhere in this issue.*]

FACTORS IN SETTING UP A COMPUTER PROBLEM

As illustrated above, computers can be applied to a number of engineering problems. In general, they offer greater accuracy, faster results, and lower costs. But before a problem can be solved on a computer, there must be an engineering investigation to establish the method of attack, the equations or procedures, the inputs, desired outputs, and the number of cases. The problem must be expressed clearly and the method of solution must be known. The digital computer, at its present stage of development, can not solve a general problem but must be *instructed* as to how to proceed.

After engineering analysis, computer programmers are usually consulted to settle questions of precision, numerical methods, and alternative procedures. This results in a general flow chart which shows the selected method of operation in block form. There follows the detailed coding of the instructions for the machine. Here, the programmers may resort to special programming languages, such as ALGOL, to transfer partially the burden of writing machine instructions from themselves to the computer.

Recent strides in the development of programming languages have made it easier for an engineer to code his own problem if he so desires. Originally the translation from problem language, e.g. strings of mathematical symbols, to machine language, e.g. strings of *0*'s *and 1*'s was a time-consuming manual operation. Today it is possible for a machine user to take his original problem statement, rewrite it to conform to, say ALGOL, terminology and rules, and then to run it on any digital computer for which an ALGOL compiler program is available. The latter program provides automatic means of translating to machine code.

Machine time is needed to debug the program, which in a complex problem may contain from 1,000 to 10,000 instructions in machine code, and to perform the computations. The results are usually printed out for the problem originator, who must determine whether the answer seems reasonable. It is well to insert test problems for which the answers are more or less known.

The cost of using a digital computer can be estimated for a given problem by an experienced programmer, who must consider two factors. One is the manpower expended in programming, the other is the machine rental time. The latter, for a large machine, can amount to several hundred dollars per hour. Balancing this is the saving in engineering time and possible gains in schedule. With some problems, the digital computer offers the only feasible method of solution, and in this case the cost in dollars may not be an important consideration.

CONCLUSIONS

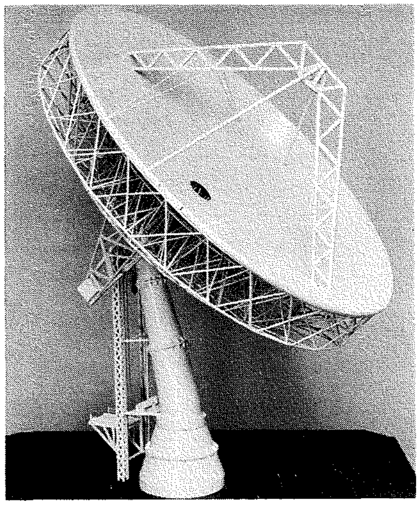
Digital computers can be powerful tools in engineering applications. The cost of using these machines has steadily decreased, resulting in a wider field of application each year. Computers are capable both of solving extremely difficult problems and of assisting engineers in relatively simple data reduction applications where a large amount of computation must be carried out.

The growing number of successful non-numeric applications e.g. cable routine, blueprint record keeping, ECN processing, suggest that engineers should consider as many tasks as possible for mechanization. Digital computers can not yet think, but they can swiftly and efficiently carry out a programmer's instructions to arrive at urgently needed results. Computers are rapidly becoming indispensable to engineers in developing complex equipment which must be put into operation before new advances make it obsolete.

REFERENCES

1. Miller, H. S., RCA Princeton Laboratories, private communication.
2. Jarem, J.; Chapter 3, *MINSTREL Task Report No. 3;* "Impact Prediction and Safety Considerations"; prepared by RCA for U. S. Army Signal Engineering Laboratories, Ft. Monmouth, N. J., Contract No. DA-36-039(sc)74853; 1958.
3. For a series of articles on current RCA computers, see RCA ENGINEER, Vol. 6 No. 4, Dec. 1960-Jan. 1961. Also, see p. 45 of that issue for a bibliography of additional RCA ENGINEER computer articles.

On March 1, 1961 a new *Antenna Skill Center,* under the direction of F. Klawsnik, Manager, was formed at the DEP Missile and Surface Radar Division, Moorestown, N. J. The formation of the Skill Center signals the initiation of antennas as a formal product line. This new activity includes a full range of capability, from research to production, covering all electrical and mechanical aspects of antennas and associated equipment for both commercial and military applications.



PEDESTAL DESIGN

The design of antenna reflectors and the supporting base, including the drive mechanism, will be the responsibility of an antenna pedestal activity. This group will interpret antenna requirements in terms of mechanical-design and mechanism criteria, including boresighting, as required. Current and long-term investigations are being made toward designing for simplicity and economy. Hydraulic, pneumatic, electronic, and other types of drive systems are being explored.

NEW ANTENNA SKILL CENTER FORMED AT MOORESTOWN

The new Skill Center will combine the efforts of several groups that already existed at Moorestown with that of a Princeton Antenna Research unit formerly under the direction of Dr. G. H. Brown, who is now Vice President, Engineering, for RCA. This combination of skills provides the technical competence necessary to meet the competitive situation developing in the industry.

In keeping with its objective of creating and maintaining technical and managerial leadership for RCA in all phases of antenna research and design, the responsibilities of the Antenna Skill Center are to:

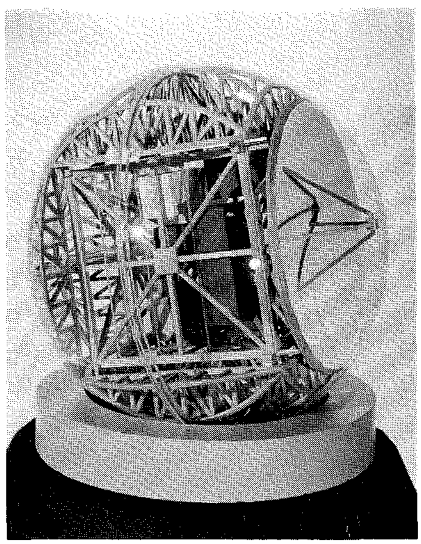
1) keep abreast of the field of antenna development and customer needs,
2) advance the state of the art in the field of antenna development, and
3) provide assistance throughout RCA on antenna design problems of both an electrical and mechanical nature.

RESEARCH

The research groups, by working toward advancing the state of the antenna art, will be in an excellent position to supply consultation services to other RCA engineering activities and to assist in intergroup communication concerning antenna problems. They will maintain a comprehensive antenna library and will have available special test facilities to permit diversified antenna experimentation.

ELECTRICAL DESIGN

This group will be responsible for the



reduction to practice of techniques developed within the research group and for the electrical design of antennas for specific applications. The experience range of the group encompasses all types of antennas. Major engineering effort is now being devoted to the study and design of electronic scanning antennas and monopulse tracking antennas with random polarization capability. Also being studied are noise-temperature considerations.

Editor's Note: Credit is due Harlin A. Brelsford, Manager, Mechanical Microwave Unit of the DEP Missile and Surface Radar Division, Moorestown, for supplying the information on this new activity.

RADAR STRUCTURES

A group has been organized to completely engineer the structural design and field emplacement of antennas, especially those which are large and of specialized nature. Dynamic characteristics of the antenna are integrated with soil studies, ship engineering, and other motion-producing criteria, in order to evolve a final mechanical design. Special emphasis is being placed on research, including efforts to develop new approaches into structural design and analytical techniques.

SERVO ENGINEERING

Important to the accuracy of an overall drive system of a moveable or rotatable antenna is the angle-servo power equipment required for accurate positioning of the pedestal and instruments for transmitting data and error-correction information. The servo engineering group is active in this field and will perform servo-loop analysis and synthesis. At the present time, this activity is engaged in advanced research on electronic scan techniques, servo drive and controller systems, and velocity-error-sensing techniques.

. . . IN SUMMARY

Antennas have grown from a relatively simple receiving or radiating element to complicated electronic and mechanical devices closely related to overall system performance. Because of their complexity it is necessary to have a research-and-engineering team with special interests to deal with the intricate problems of antenna development. The *Antenna Skill Center* has been established to meet these needs.

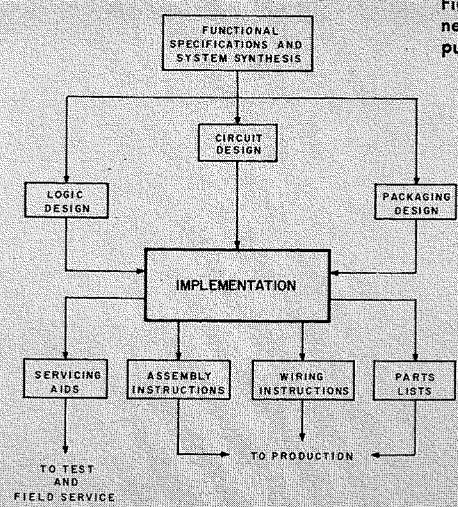


Fig. 1—Flow of engineering effort in computer design.

AUTOMATED DESIGN

Translation of concept into hardware can involve a tremendous amount of detailed, time-consuming engineering effort — especially in the design of data-processing equipment. The successful use of the digital computer to generate wiring data has important implications for automating more of the details implicit in the design process.

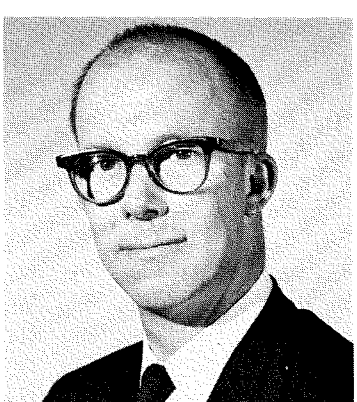
R. A. C. LANE, Mgr.
Electronic Data Processing Center

and

J. E. PALMER, Mgr.
Computer Design Engineering,
Data Communications and Custom Projects Dept.
Electronic Data Processing Division, IEP, Camden, N. J.

ROBERT A. C. LANE received the A.B. in Physics from Indiana University in 1950. He taught Mathematics for two years at Lehigh University while doing graduate work in Mathematics, then joining the RCA Computing Systems Engineering Dept. in 1952. There, he participated in EDP systems and applications analyis. In addition, he was instrumental in the development of test, diagnostic and service programs, and participated in customer assistance. He was then appointed Engineering Leader, supervising these functions until January 1957, when he became Manager of the newly formed Electronic Data Processing Center in Camden, responsible for EDP service to other RCA departments and to external agencies, a prominent application being automated design. Mr. Lane is a Member of Pi Mu Epsilon, ACM, and Mathematical Association of America. He is currently Ass't. Chairman, Phila. Chapter of the IRE Professional Group on Electronic Computers.

JAMES E. PALMER was graduated from the University of Pennsylvania in 1953 with a B.S.E.E. degree. He joined RCA in June 1953 in the EDP Engineering Activity and was engaged in the development of punched card processing equipment. In August, 1954, Mr. Palmer entered the Army and rejoined RCA in June 1956. He returned to EDP Engineering to continue work on input and output devices in the systems design of card-reading and card-punching equipment for use in the RCA 501 System. Mr. Palmer was promoted to Leader, Design and Development Engineers in 1959, with responsibility for advanced circuit development and the design of a digital communications multiplexing system. In January 1961 he was named Manager, Computer Design Engineering, in the Data Communication and Custom Projects Dept. of the IEP Electronic Data Processing Division. Mr. Palmer is a previous RCA ENGINEER author (*Transistorized MUX/ARQ-2*, Feb.-Mar. 1960).



COMPUTERS HAVE LONG BEEN accepted as the only practical means of solving many of the complex theoretical problems common in research and development work. But, only infrequently have computers been used to relieve the design engineer of the often-overwhelming body of detail generally encountered in translating theory into practice.

The importance of this detail is emphasized in the design of electronic data-processing equipment, where large numbers of identical circuit elements are interconnected to form a huge, complex network. The design of the circuit element itself is a rather small part of the total man hours of effort. The design of the network is a much larger part, and the transformation of this design into specific instructions for mounting and interconnecting the myriad component parts is often a staggering task. Thus, a relatively small amount of creative effort generates a mountain of detail which must be organized and presented in meaningful terms before the fruits of creativity—the hardware—can be produced. Computer techniques can be used to automate much of this kind of design detail. As described herein, computer generation of wiring data has been proven practical and economical, and substantially more is possible.

COMPUTER DESIGN

Fig. 1 shows a typical sequence of events in the design of electronic data processing equipment. The first step is the generation of functional specifications which describe what the equipment is to do and the conditions under which it must operate.

Basic Approach

With these as a guide, the logic of the system is developed, the circuits are designed, and the packaging concept is formulated. In a completely new design, these three tasks are closely related and are certainly creative. The basic circuit must fit the needs of the system with regard to speed and function. It must be matched to cooling considerations inherent in the packaging concept. The package must provide for a dense population of logic elements, ease of interconnection, efficient trouble-shooting, and quick replacement of faulty components. The output from this phase of the design is threefold:

1) a detailed description of the system logic in the form of diagrams or equations, or both;

2) a catalog of logic elements available for implementing the system with the characteristics of each specified; and

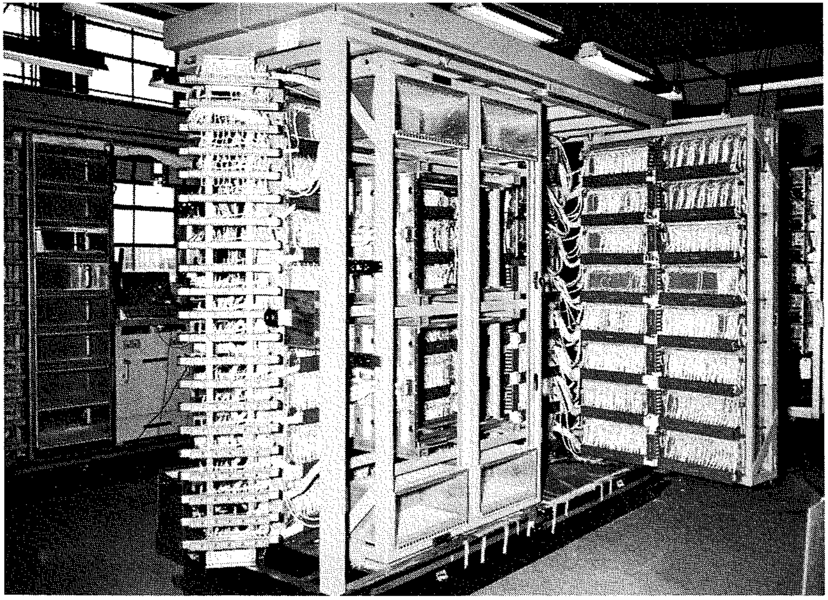


Fig. 2—BMEWS 8-in-1 cabinet.

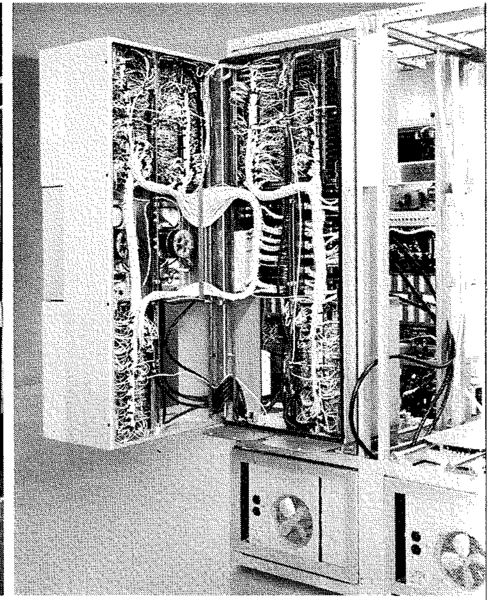


Fig. 3—ComLogNet rack. (Far right.)

3) a set of detailed rules governing the interconnection and mounting of the logic elements, with all constraints imposed by packaging and circuit design expressly stated.

In many cases, items 2 and 3 are already available as standards and are used directly, thus eliminating the need for circuit and packaging design.

Design Implementation—Potential for Mechanization

The next step in the design is a large one. It is not particularly creative, and usually very complex. *It is exceedingly well suited to mechanization.* It involves the implementation of the design (which, in effect, is complete) using the catalog of available logic elements and combining them in accordance with the rules to produce the completed system. Upon completion of this process, the results must be presented in two forms; one form simplifies servicing and the other is required for manufacturing.

For servicing: A detailed description of the system logic, using diagrams or equations, or both, showing what available logic elements were used and for what purposes, the physical location within the package for each logic element, and designations for all connections and test points.

For manufacturing: Detailed instructions for the installation of interconnecting wiring showing the type of wire to be used in each case, the method of terminating the wire, the origin and destination of the wire, and the route the wire must follow.

To give some idea of the magnitude of this task, the RCA 503 Computer contains some 19 different logic elements mounted on 71 different plug-in types. There are 37,141 separate connections in the system, 6 types of wire and 5 types of terminations. Literally hundreds of drawings are necessary to detail the logic and specify the wiring for such a design.

As mentioned before, the characteristics of the package in which the unit is to be housed have a profound effect on the final design. If the basic logic element can be made equal to the basic physical element, then the *rules* for implementing a design may be rather simply stated and automatic methods may readily be applied. Substantial complication results if, through miniaturization or other advances in the art, it becomes necessary to house many logic elements within a single physical element. Such is the requirement of present-day equipment. Implementation of a design requires not only a description of interconnections, but also a specification of the contents of each different type of physical element (usually printed-circuit plug-ins). The requirement for plug-in specification introduces the whole field of printed-circuit packaging with its problems of topology, printed-circuit standards, connection limitations, etc.

Thus, before a computer can proceed with the generation of wiring tables, the design of the plug-ins must be established, which involves many complex factors. For example, shall major emphasis be placed on generality of purpose, with a resultant increase in the total number of plug-ins used?; or, should the effort be directed toward minimizing the total number of plug-ins through the use of a large number of specialized plug-in types? Or, is a compromise best? Is it better to reduce the physical size of the plug-in, thereby making the basic physical element more nearly equal to the basic logic element? The complexity of this problem has precluded the effective use of automatic methods in its solution to date. However, once the plug-ins are specified, computers can and do take over the burden of interconnecting them.

WIRING DATA GENERATED BY COMPUTERS

Early in 1958, using a much simplified approach, an EDP system was used to produce a set of wiring schedules for the construction of the electronics portion of the 501 Card Transcriber, a two-rack unit. Later, a group from the DEP Missile and Surface Radar Division at Moorestown conceived a method of designing cable harnesses for the BMEWS 8-in-1 cabinet. Programs were developed by the EDP Division in accordance with the rules set by M&SR Engineering, and the cable design for 21 BMEWS cabinets was computer-produced. Eleven of these cabinets were Tracking Radar (TR) units and ten were Control and Switching (C & S) units. The computer output was a double-entry *from-to* list with each wire requiring two printed lines. The C & S units contained an average of about 8000 wires per cabinet, requiring approximately 600 pages of output for each. The printing time for each cabinet was about 45 minutes. The TR units contained an average of 600 wires per cabinet and required proportionately less printing time.

Processing for each cabinet included provision for data verification, assigning terminal board positions when branching was required, routing of the wires and handling of engineering changes.

General-Purpose System for Digital-Equipment Design

A general purpose system has since been developed for use in the design of computers and other digital equipments which utilize packaging techniques that are quite different from the BMEWS 8-in-1 cabinets. The system was to be applicable to the EDP product-line computer systems and to the USAF ComLogNet system. This automated-design system has been continually improved and is currently being used in the design of the

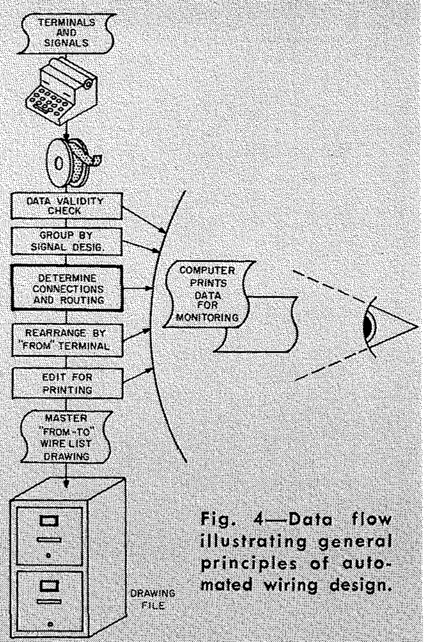


Fig. 4—Data flow illustrating general principles of automated wiring design.

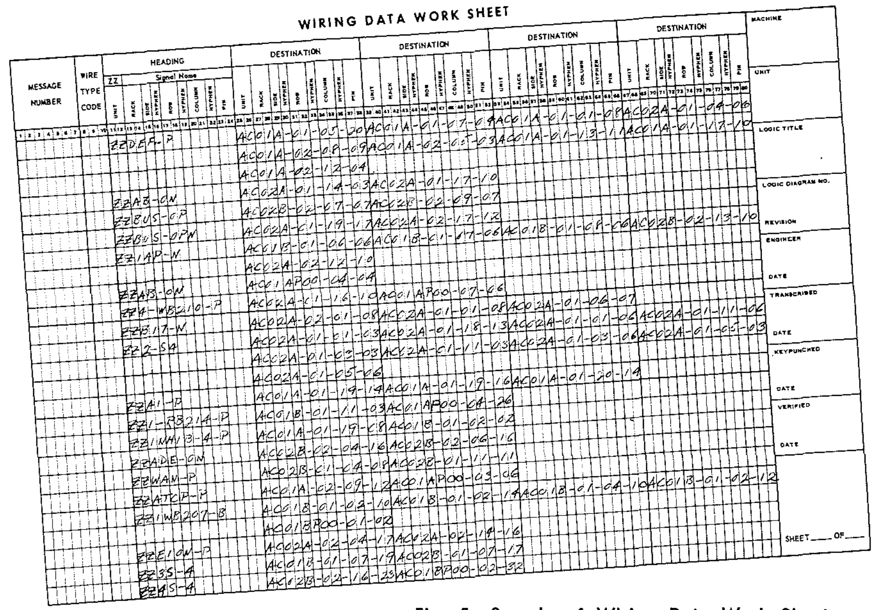


Fig. 5—Sample of Wiring Data Work Sheet showing information used as input to the computer for automated wiring design of ComLogNet equipment.

ference between the BMEWS and the ComLogNet equipment. The major dif- ComLogNet System is in the packaging and in the ground rules for determining the proper connections and routing of the wires.

Fig. 2 illustrates a typical BMEWS 8-in-1 cabinet. The computer's job was to design a cabling network which connected chassis mounted on the cabinet doors. It required extensive use of terminal-board connections for branching. The ground rules for routing of the wires are relatively complex: for example, the computer must determine which of the terminals having a common signal is the *source* and which the *load;* it must then select the unassigned terminal board nearest to the source, decide into which of four classes the signal belongs, and select the proper one of four horizontal channels in which to route the wires; if cross-over point from one side of the cabinet to the other is required, then the cross-over point nearest to the source terminal board must be used.

On the other hand, the ground rules for the ComLogNet project are substantially different. A typical rack is shown in Fig. 3. Submodules mounted on printed-circuit boards are inserted into a rectangular two-dimensional array of receptacles mounted in the rack. The problem, rather than being one of cabling, is to connect all receptacle terminals having the same signal within a given subunit. No terminal boards are required, since more than one wire can be connected to each receptacle terminal to permit branching. The routing problem is greatly simplified and is even nonexistent in cases where wires are connected directly in a straight line between two terminals. Typical ground rules for connecting the wires are: no more than three wires per terminal; no closed loops; one of three wire types (coax, twisted-pair, and regular wire) must be used based on the length of wire required.

A unique feature in the ComLogNet system is the need to determine a way of connecting more than two terminals which will result in the minimum length of wire. The program is designed to determine an optimum network for connecting up to thirty-five terminals. This is an arbitrary limit and could be extended if required.

This requirement results from a need to minimize wire length in order to achieve good circuit performance. It is also necessary in determining the type of wire to be used in a given connection, since long runs require coaxial cable and shorter runs do not. Total length of wire per signal and total length of wire per wire type are useful by-products of the process.

How the Computer Is Used

Although the packaging of commercial digital systems is considerably different from the BMEWS concept, the basic principle is the same. A general-system which illustrates the principle is shown in Fig. 4.

The input (Fig. 5) furnished by the engineer consists of two basic elements, a terminal and the signal that must be applied to or eminate from that terminal. The input form shows the signal name and a list of terminals to which that signal applies. It is convenient, but not absolutely necessary, to define a terminal by its location. For example, in the BMEWS application, the cabinet number, door number, plug number, and pin number are sufficient to locate any specific terminal in the system. For ComLogNet, terminals are defined by specifying a unit, rack, row, column, and plug-in pin-number. The signal name can be any unique configuration of letters and numbers. From the engineers' viewpoint, it is desirable that the signal name consist of words or abbreviations whose meaning can be readily understood and recalled; from the standpoint of the computer, it is only important that consistency prevail throughout the entire system.

The data supplied by the engineer is presented to the computer as punched cards or punched paper tape. The first computer operation is a validity check to prevent errors, which may have been made in the initial preparation of the data, from influencing the final output. Manual corrections may be made after the validity check. The next operation is to rearrange the data on the basis of unit (if more than one unit is being processed at one time) and within each unit by signal name. This merely rearranges the data such that all terminals having the same signals are grouped for further processing.

Continued accuracy control is automatically provided wherever possible. For example, the computer is programmed to become suspicious and to inform the operator if a signal name appears with only one terminal. This situation, if undetected, would result in a wire being connected at one end only.

Using predetermined ground rules, the computer determines the best way of connecting all terminals having a common signal. It assigns terminal-board positions (if terminal boards are used). It remembers what assignments have not

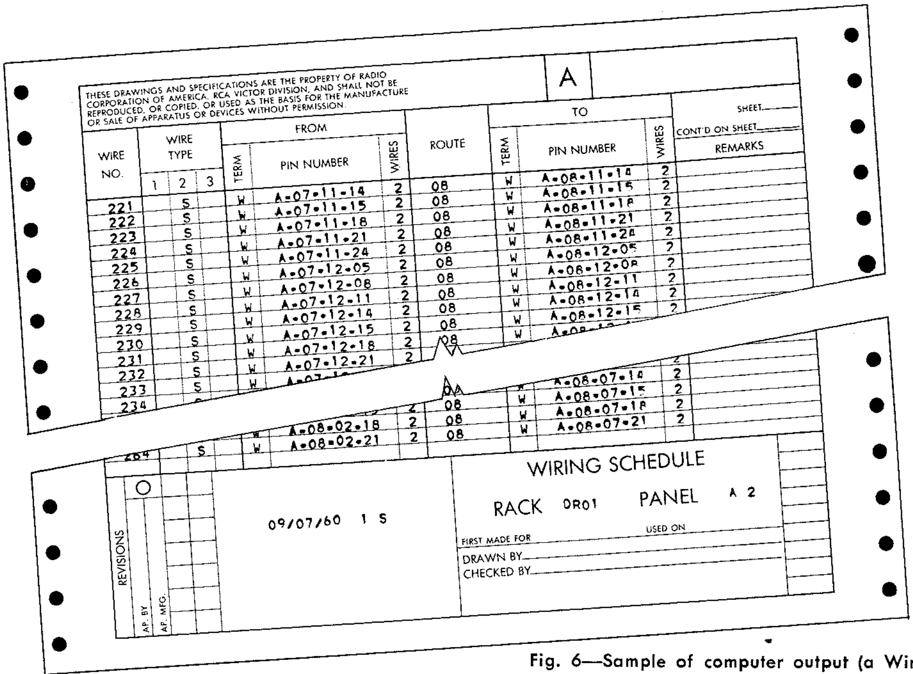


Fig. 6—Sample of computer output (a Wiring Schedule) for ComLogNet equipment.

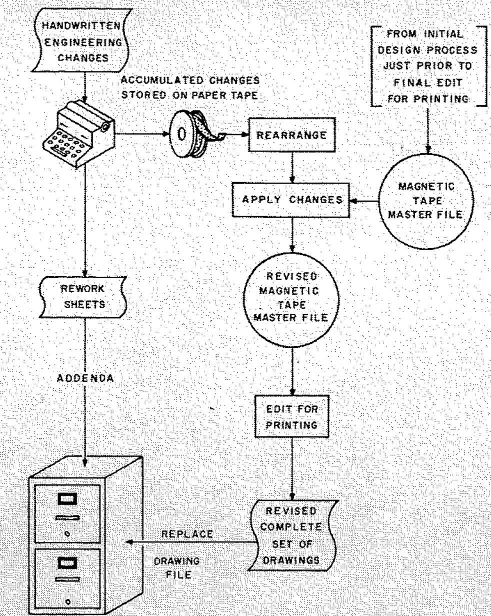


Fig. 7—Handling of engineering changes.

been made and uses this knowledge in subsequent connections. It determines the routing of the wires, wire types, wire lengths, and so on.

The data at this stage is in *from-to* form with one *from-to* entry for each wire in the unit. It is next expanded to double-entry form by duplicating each *from-to* entry with the *from* and *to* locations interchanged. It is then sorted to provide easy reference to any terminal in the unit, together with all associated connections, by arranging it in ascending order, according to *from* terminals. An editing process suppresses unwanted symbols and aligns the data for printing in the proper format. An example is shown in Fig. 6. Despite the variation in construction of computer equipment, the basic principle and the ultimate objectives are identical—the preparation of wire lists which can be used by the factory to produce the product.

The output data is reproduced by a high-speed printer on translucent carbon-backed preprinted forms, which become the master tracings usable in normal duplicating processes.

ENGINEERING CHANGE METHODS

Once wire lists are complete, some provisions must be made in the computer system to handle engineering changes. Most changes can be accommodated by considering them as wire additions or deletions. But it is important that changes be applied to the data as it exists toward the end of the initial processing, rather than at the input stage. The reason for this is that a change of input would require a rerun of the entire process. This is not only costly in terms of machine time, but more important, it could completely change the design by requiring the revised data to pass through the design cycle a second time.

The change process currently in use is shown in Fig. 7. Changes which add wires or delete wires are recorded on a form identical to the original computer output. All information, such as addition or deletion of wires, wire type, name of signal, terminal locations, is furnished. In the case of wire deletions, a marked copy of the original list is sufficient. These changes are then typed onto a reproducible form and placed in the drawing file as an addendum with a paper tape being a by-product. The resulting tapes can be used to revise the complete drawing file whenever necessary.

WIRING DATA VERIFIER

Another useful feature of the system is the wiring-data verifier, a set of programs which considers the logical and electrical parameters of the logic elements. It utilizes knowledge of the assignment of terminals on specific plug-ins, the location of the plug-ins in the rack, and the loads the plug-ins can drive, to verify the accuracy of the input data. Adequate control of input data preparation, as is the case with most EDP applications, has been found to be the weakest link in the process; in general, the more automatic checks provided at the beginning, the better the results. To date, insufficient experience in the use of wiring-data-verifier routines has connection networks appear to be achievable. Logic simulation to permit exhaustive testing of designs during the been accumulated to evaluate their effectiveness as an accuracy control. However, the real significance is the introduction, storage and automatic use of logical and electrical data in the process.

CONCLUSION

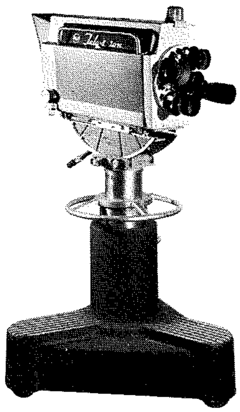
The economy and practicality of using the computer as an aid to design has been proved. It is evident, however, that substantially more is possible.

Methods for preparing computer input-data have been found to require improvement; the natural next step is to devise a way of recording the actual logic of the unit in a form more acceptable to the computer. Boolean algebraic expressions have been used successfully for designing computer logic and provide data that is directly usable in an automated process.

The storage of logic diagrams and basic circuit data in a form directly acceptable for automatic processing has many interesting possibilities. Optimization of design, over-all logic design of systems, placement of modules for more effective packaging, and optimum inter-early development stages also seems possible. To carry these possibilities even further, it is quite conceivable that the computer can be programmed to furnish comprehensive reference data or servicing manuals as a by-product of the design process.

Substantial effort has been expended at RCA and throughout the electronics industry to date. Even more effort is required to realize the full potential of a computer as a design-engineering tool. The speed with which progress can be made in these areas is, however, directly proportional to the interest shown by the engineering groups that could benefit from these computer techniques.

AUTOMATION IN TV STATIONS



by **FLOYD R. McNICOL, *Mgr.***
Broadcast Systems Group
Broadcast and TV Equipment Division
IEP, Camden, N. J.

THE GREAT COMPLEXITY of present-day TV programming coupled with increasing cost is bringing automatic control equipment to many TV stations. This involves a kind of "custom engineering" of the automation equipment, since broadcast studios vary widely in their programming requirements—often based on close cooperation between the TV-station engineers and the RCA broadcast systems engineers.

FACTORS BEHIND AUTOMATION

Manually controlled equipment, with its complement of personnel, may not satisfy all of the many switching and operating requirements to get the right picture and sound on the air at the right time. This has forced the development of more accurate and efficient techniques and equipment for the frequent switching from one program source to the next. This process of *program assembly* is extremely important at any TV station. It involves a long sequence of non-repetitive functions, different from hour to hour and day to day, but arranged according to a definite, predetermined plan.

Often, there are relatively long intervals between successive functions, but at other times there is a very rapid sequence which, if handled manually, requires a high degree of skill to avoid costly errors. Such sequences usually occur during a station-break and involve a group of short commercials and announcements. Any minor error during this "panic-period" can result in interruption or loss of such commercials, with a consequent request for a refund.

The interest in automatic preset switching first developed around this critical panic period. Now, in addition, the general idea of automation is being extended to a much larger category of problems in program assembly, with accompanying savings in labor cost. Considerable progress in designing useful systems and equipment has already taken place, and several TV stations are using such equipment successfully.

AUTOMATION EQUIPMENT

Equipment requirements depend on a number of factors, such as space available for equipment and the nature and number of local programs, rehearsals, remotes and network feeds.

Film and slide projectors, and TV and audio tape recorders are but a few of those equipments found in a broadcast plant. Their control functions include a wide variety of operations, such as starting, stopping, changing slides, and rewinding tape; simultaneous or separate switching of audio associated with video signals; switching of network and other remote feeds; and switching of studio outputs. In special applications like news or interview programs, the remote control of "robot" cameras may be involved (Fig. 1). Fig. 2 illustrates a typical group of equipments controlled by automatic switching.

The automation equipment may consist of a control console and two to four racks of modular components and relays (Figs. 3, 4). The console contains controls to allow combination of the proper programs, and a readout panel which may consist of a number of windows for illuminated numerals indicating the elapsed time, the source of the video signal and audio signal, and the event number in the program. Some installations may have the readout panel near the monitors.

The racks for an automated system controlled by punched paper tape, contain the necessary power supplies, control and memory relays, stepping relays, and the master clock. This electro-

Fig. 1—Remote control of robot TV cameras. Operator is using "joy stick" for pan and tilt; with his left hand he operates switches for zoom and focus.

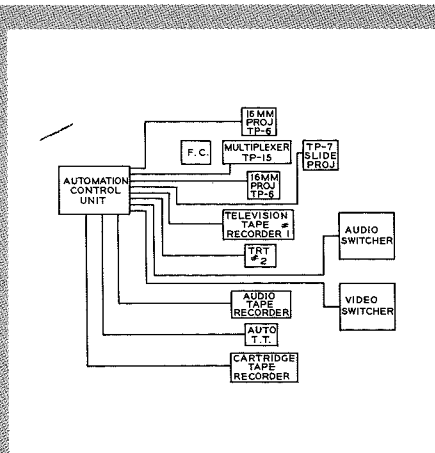
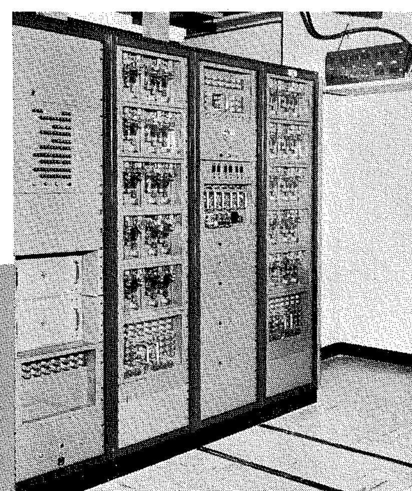


Fig. 2—Diagram of a typical group of equipments controlled by automatic switching.



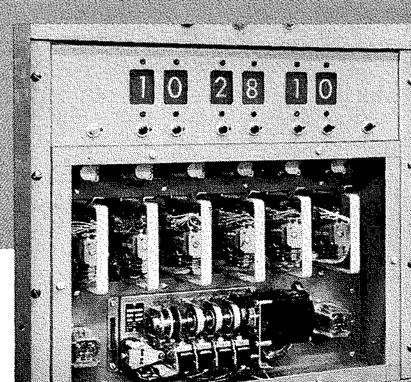


Fig. 3—Bottom: Precise electromechanical clock used to time switching of events. It is located in the racks (top) that contain the control and memory relays, stepping relays, and power supplies.

mechanical clock (Fig. 3), set with a tuning fork, is used to time the precise second that a switch is made to put a program or commercial on the air. Events can be spaced as close as three seconds apart.

The clock also provides real-time information to the readout panel. The control paper tape is advanced to the next event when an event ends either by time coincidence or manual control.

Some of the other RCA equipment, which is used in many automated studios are the TS-40 transistorized video switching equipment, automatic light control, TP-7 TV slide projector, TP-6 professional film projector, and TP-15 universal multiplexer. One recent custom installation required 1,653 pieces of equipment and 32 miles of wiring.

SYSTEM OPERATION

One type of RCA's automation equipment has been designed to handle from 10 to 15 video and audio sources and 10, 15, 20, or 25 events. (An event is an item in the program schedule which involves a change in video and/or audio sources on-the-air.) Audio and video sources are selected by the operation of the video-source selection button when the interlocked audio source is desired; if not, selecting any audio source over-rides the interlock (e.g., network audio with network video; slides with announcements).

The degree of automation depends on the type of control needed for reduction of peak workload. Three methods are most common: *minimum station break, station break,* and *all-day tape-controlled.*

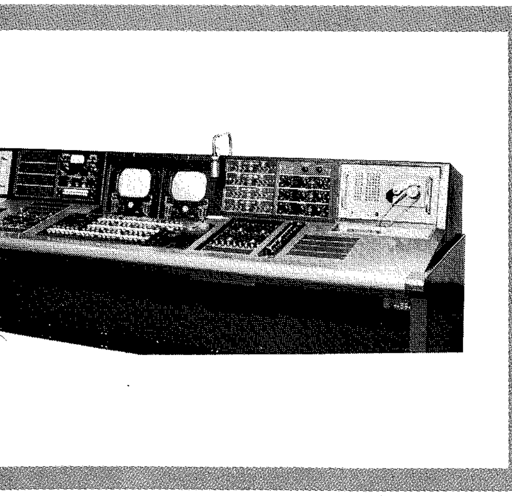


Fig. 4—A master control console. At the left end is the primary control tape panel, while at the right end is a similar panel for the correction tape.

Minimum Station Break (Preset-Manual-Go Ahead)

The necessary function controls are preset during a slack operation period, and at the proper time, a button is pushed, starting an event or series of events. By the operation of one or two buttons in place of the many normally required, an event is placed on the air.

Station Break (Preset-Feedback, Time or Manual Operation)

This is a logical expansion of the above, with event-actuation control accomplished normally by feedback (the control signal starting the next event originates in the machine on-the-air) or elapsed time operation, or by manual control if desired.

All-Day Tape-Controlled (All-Day Programming Control)

This system allows operation with an absolute minimum of supervisory control and approaches the ultimate goal of TV Automation. It avoids repeatedly presetting the control information in the memory.

This system (Fig. 3) is controlled by an eight-channel punched paper tape that is a by-product of the typing of the daily program log. The information for each switching event is contained in ten rows of holes in the paper tape and includes the video and audio sources, and the time at which the switching is to take place (whether actual or approximate, or by manual actuation). The control tape, which may guide all operations of even a 24-hour day, is placed on a tape reader prior to start of the day's programming. The tape is read into the control-circuit relays by the block tape reader, which reads all the possible 80 holes simultaneously. The second reader allows a correction tape. It takes over at the proper time to insert required changes and returns control to the primary control tape after the correction. The source-selector relays trigger switching at the proper times. (Provisions are made to expand the number of selector relays as needed.) Signals routed through the relays include control information for such operations as video and audio switching, projector and TV-tape advance-start, multiplexer and/or douser operation, slide change, audio tape recorder and turntable starting. The decoding operation includes source decoders and time decoders. The source decoders cause selector relays to set up the signal paths; the time decoders supply signals for comparison with a master electronic clock to determine when time coincidence occurs.

The lone operator at the control console follows the readout panel and monitors. If a remotely controlled camera set-up is being used for live TV broadcast, an additional operator would be used as shown in Fig. 1. Placement of the cameras is done by hand in advance of the program, but depth of focus, close shots, pan shots, and up-and-down scanning are remotely controlled.

FUTURE SYSTEMS

As TV station commitments and schedules have become tighter with greater information-storage needs, new approaches are being sought to combat operating costs and ever-present human error.

One engineering group is now investigating the application of modern computer techniques to broadcast studio use. Storage of the entire day's program at the beginning of the day, rapid access to all items in memory, reduction of the minimum event length to 1 second (from the 3 seconds mentioned), and the ability to expand or change computer control functions are some of the more important things which led to computer consideration.

FLOYD R. McNICOL received his BSEE degree from Kansas State College in 1937. He attended Navy Radar schools at Harvard, MIT and Corpus Christi in 1942-43. Following this, he served as Radar Officer in a Navy Squadron from 1943-44, and in Special Weapons Systems in the Bureau of Aeronautics from 1944-46. Mr. McNicol has had extensive experience in the planning, construction and operation of a TV station as Assistant to the Chief Engineer of WGN in Chicago during the period from 1946-57. In 1957 he joined the Systems Group in Broadcast Studio Engineering in the Broadcast and Television Division, IEP. He is presently Manager of the Broadcast Systems Group. Mr. McNicol is an Associate Member of the IRE.

TELEMETRY GROUND STATION ... ACC's New Castle Facility Provides Data-Reduction Services

by **H. C. MONTGOMERY**
New Castle Engineering Facility
Aerospace Communications and Controls Division
DEP, New Castle, Delaware

At the New Castle, Delaware Engineering Facility of the DEP Aerospace Communications and Controls Division, data-reduction and analysis services are available which should be of interest to RCA engineering groups concerned with the evaluation of magnetic-tape or telemetered data. A variety of integrated equipment comprises the system, which their Instrumentation Engineering Group designed.

THE TELEMETRY GROUND STATION (Fig. 1), constructed at a cost of approximately $350,000, contains a variety of equipment incorporating many unique design features. The equipment (Fig. 2) was concurrent with existing state-of-the-art at the time of its design and has since proved to offer a high degree of reliability and accuracy. The over-all system provides the following wide range of operating capabilities:

1) The processing of large quantities of data at high production rates from either 1-inch or 0.5-inch magnetic tapes.

2) The processing of standard FM-FM, PAM, PDM, WBFM, and AM modulated tape data recorded at various tape speeds (60, 30, 15, 7.5, 3.75, 1.875 ips) and sampling rates.

3) All output data may be correlated in elapsed fiducial time and read out in convenient engineering units. Data presentations may utilize conventional oscillograms, strip charts, meters, scopes and/or totalizing counters.

4) Maximum flexibility of interconnection and programming allows tape format changes, different configurations for each flight or run, and optimum trace-grouping of related functions for the convenience of the analysis engineers. It facilitates convenient shift operations for entirely different programs.

5) The system is capable of applying all necessary data corrections to avoid subsequent manual handling of data. Such corrections include zero drift, sensitivity changes, tape speed error, tape flutter, wow compensation, and full scale limiting.

6) Necessary standard equipment for internal calibration within desired accuracy requirements is provided.

7) The system is capable of both forward and reverse playback of data for analysis of events in both sequences.

INPUT EQUIPMENT

The input equipment consists of a magnetic-tape transport, associated record-reproduce circuitry, and a complementary telemetry analyzer. An associated three-point calibrator, a signal generator, signal-conditioning units, and an input patch panel are also provided.

Tape Transport

The tape transport is a 14-channel recorder-reproducer equipped with direct (AM), frequency-modulation (WBFM) and pulse duration modulation (PDM) *record* and *reproduce* amplifiers; the transport is capable of handling 1-inch or ½-inch tape widths.

A high-speed capstan allows tape search in either the forward or reverse direction at 120 ips. This feature, when incorporated with the proper time code control, provides an accurate method for reproducing any selected portion of data.

An electronic speed-lock servo system insures that *record* and *playback* tape speeds remain relatively the same (±0.1 percent). This arrangement corrects for either the real or apparent error associated with magnetic-tape equipment. It operates as a constant-current generator during recording, and frequency equalization is provided on playback. Frequency response is ±3 db from 100 cps to 120 kc at 60 ips (signal-to-noise ratios are 60 db).

A unique advantage offered by magnetic-tape recording is the compression or expansion of the *record* time base. This is performed by either increasing or decreasing the *reproduce* speed relative to the *record* speed. Information, therefore, may be placed in a more convenient form for either analysis or further processing.

Telemetry Analyzer

This subsystem is comprised of a three-point calibrator, spectrum analyzer, indicator and necessary regulated power supplies. The unit provides a simple, reliable method for checking system operation and calibrating channel center frequencies and channel limits within the approved FM-FM telemetry band. The following types of test results are provided:

1) channel location and relative noise level;
2) intermodulation distortion;
3) indication of disturbing spurious signals;
4) adjustment of pre-emphasis curves;
5) precise, rapid calibration of subcarrier discriminators and appropriate readout devices;
6) spectrum analysis (frequency versus amplitude) of any complex wave between 350 and 85,000 cps.

The telemetry analyzer is equipped with a calibrated CRT screen in both logarithmic and linear scales so that permanent photographic records may be obtained.

Signal Generator

This unit is basically a telemetry oscillator used to simulate particular parameters for setup, checkout and maintenance of the ground station.

Signal Conditioner

The power amplifier and line amplifier units comprise the necessary signal conditioning, providing necessary amplification, scale factors, impedance matching, and signal shaping between the magnetic-tape *reproduce* amplifier and the desired readout or decoding equipment.

DEMODULATION-DECODING UNIT

This equipment is designed to demodulate frequency and time-multiplexed data. In essence, it will separate a complex waveform comprising many channels of information into individual signals proportional to the original recorded parameters.

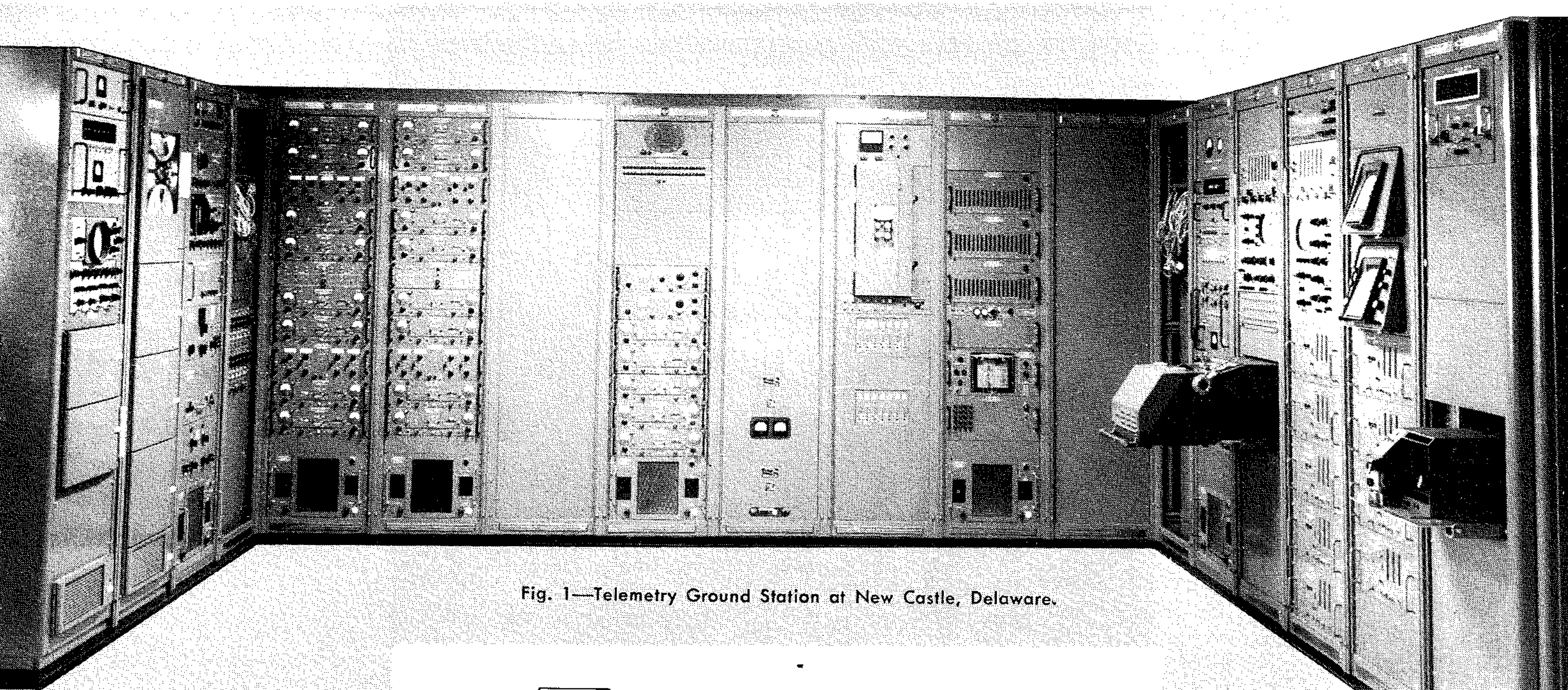


Fig. 1—Telemetry Ground Station at New Castle, Delaware.

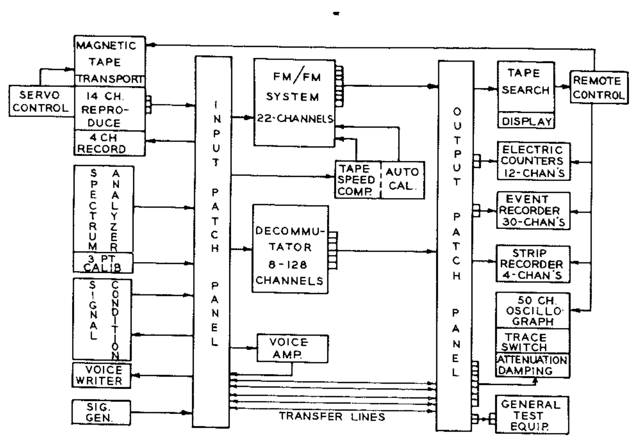


Fig. 2—Functional block diagram of the data processing center.

Fig. 3—Center frequencies of particular subcarrier oscillators and companion FM discriminators in a typical FM-FM system. Input circuits of the subcarrier oscillators are amplitude-conscious; outputs are FM-modulated carriers, linearly mixed to produce a composite waveform for transmitting and/or recording over a single channel. Detection is with bandpass filters for selectivity and FM discriminators for demodulation. Outputs are analog voltages proportional to the amplitude and frequency of the input.

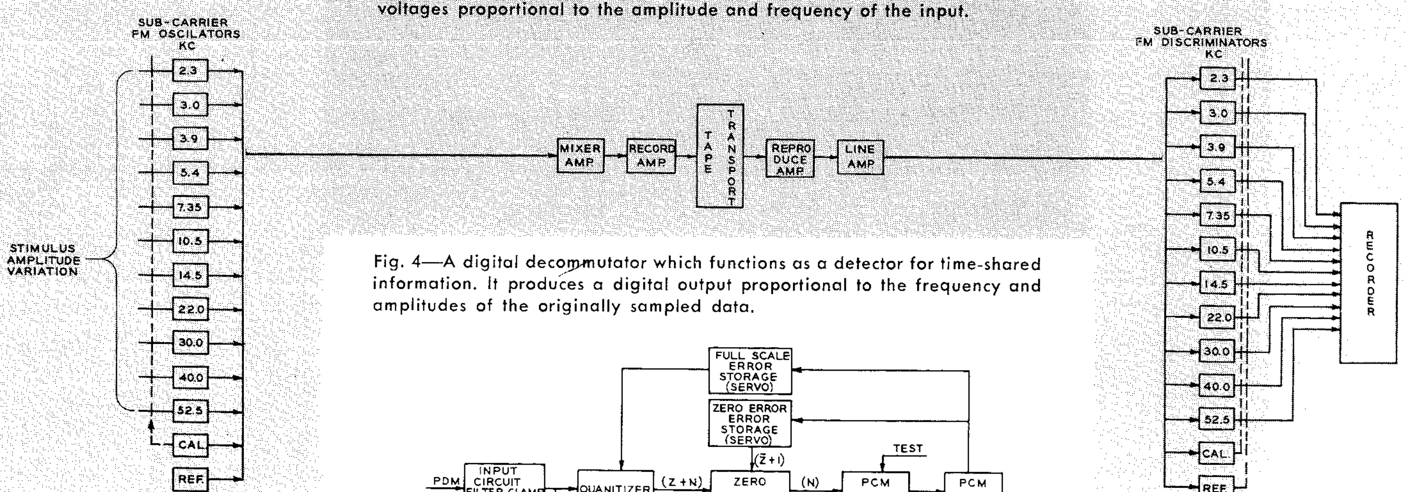
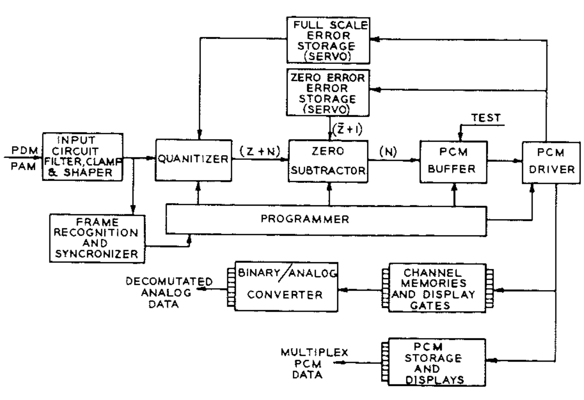


Fig. 4—A digital decommutator which functions as a detector for time-shared information. It produces a digital output proportional to the frequency and amplitudes of the originally sampled data.



Subcarrier Discriminator

The ground station is equipped with twenty-one FM discriminators, (Fig. 3) tuned by a single front-panel plug-in unit having an active bandpass filter and an associated lowpass filter. Discriminators are insensitive to spurious signals as large as 90 percent of the desired subcarrier signals. Thus, straight-line linearity of constant slope (±0.1 percent) is provided, and the effects of amplitude modulation and step-function changes normally encountered in magnetic tape dropouts are minimized. The discriminators also provide constant time delay of intelligence through a subcarrier channel; this permits reduction of dynamic data with errors of less than 1 percent distortion at a modulation index of 5. The error is proportionally reduced to 0.1 percent as the intelligence approaches dc or a modulation index approaching infinity, where the *modulation index = (deviation) ÷ (modulation frequency)*.

The discriminators are complemented with automatic servo calibration and tape-speed error compensation. The automatic calibration, through proper programming, compensates for center frequency drift (zero drift) and sensitivity drift of the input data, characteristic of all types of FM modulation techniques. This is accomplished through an internal reference signal and a comparative servo null-balance system connected in the time-constant and feedback loop, respectively, of the discriminators.

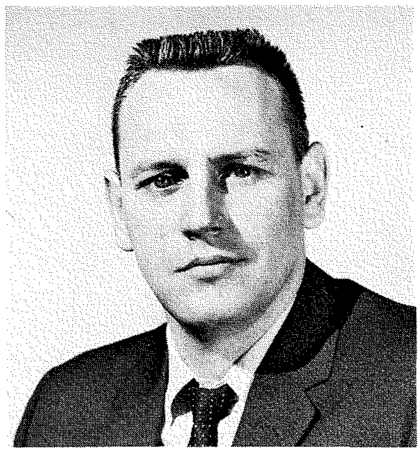
Tape-speed errors due to wow and flutter, deviation between record and playback speeds, and tape stretch are compensated for by measuring the deviation of a standard-reference crystal oscillator and supplying the resultant demodulated error voltage to the time-constant control circuits of the discriminators.

Digital Decommutator

Basically, this decommutator (Fig. 4) digitizes time-multiplexed data signals. The input circuits accept PAM, PDM and PCM data at sampling rates from 23 to 6000 pulses/second for 8 to 128 channels. In addition to three binary-decimal displays, forty-five binary displays are available for monitoring the decommutated data.

The digitized data may be reconverted to analog for a "quick-look" presentation to various readout devices. A parallel ten-bit binary multiplexed output is available to record a magnetic tape in the proper format for direct entry into a computer, plotter, or high-speed printer.

The digital decommutation system is equipped with zero and full-scale electronic servo loops to insure data validity in the event of power supply drift. A self-contained calibration unit permits simulation and calibration of the entire system including readout for any binary quantity from 0 to 1024. Linearity of the system has been measured at ±0.04 percent from the best straight line. Cross-talk is limited to 0.1 percent of full scale. The entire system is solid-state, utilizing plug-in modular boards.



HUGH C. MONTGOMERY was responsible for the design and operation of the air-borne instrumentation system for the P6M Seamaster program at the Martin Company, Baltimore, Maryland, from 1955 through 1958. Here he advanced to the position of Instrumentation Engineer. Mr. Montgomery joined the RCA Service Company in 1958 and was involved in the design of the air-borne and ground instrumentation systems for the ASTRA program. He transferred to RCA New Castle Engineering Facility in 1959 and was responsible for the design of the Telemetry Ground Station shown in this paper. Mr. Montgomery is presently involved in the design and investigation of advanced data-processing and acquisition systems utilizing combination of PCM, FM-FM, PDM and magnetic-tape techniques. He is also devoting his engineering skills toward application of instrumentation techniques in the biomedical field.

READOUT EQUIPMENT

The ground station incorporates the following readout devices. Their utilization is dependent on the type of processing required for the particular parameters involved and the desired analysis.

Electronic Counters

Ten-counters are utilized to obtain the statistical data such as would be desired for the evaluation of a digital communication system. Counters are controllable through the tape-search and remote-control unit. Statistical data may be readily obtained for any selected time interval or time base.

Oscillographic, Strip, and Event Recorders

The oscillographic recorder provides a direct graphical presentation of data for as many as 50 channels simultaneously and with positive time correlation. Two similar units are installed. The heart of the recorder is a galvanometer consisting basically of a mirror suspended from a coil; the assembly is contained within a permanent magnetic block. A variety of galvanometers provide a choice of numerous sensitivities and frequency responses. Maximum galvanometer response is 5000 cps. Recording speeds can be varied from 0.1 to 158 ips. Excellent resolution can be obtained with intelligence up to a 100-microsecond square wave.

A two-channel strip-chart recorder is utilized primarily for checkout and maintenance of the station.

A 30-channel event recorder is capable of recording *on-off* and *level-change* data. Resolution of 500 signal-changes per second is possible with accurate time-base correlation.

Tape Search Unit

The magnetic-tape search equipment operates during data processing periods on a time signal previously recorded on tape by a digital timing generator. The search unit provides the control functions necessary for automatic search and controlled playback of data sequences selected on the basis of manually set time indices. It displays the time indices associated with the data sequences being searched or played back. It also provides an output suitable for recording on the oscillograms for precision time correlation. Necessary control for the various readout equipments is maintained by a remote-control panel that obtains command data from the tape-search unit and associated manually set time indices, and from operator switch selection.

Tape-Copying Subsystem

A separate tape-copying subsystem is provided for making copies of 1-inch or ½-inch master tapes; it is also used to prepare special test tapes for use in station setup.

APPLICATION

The high degree of flexibility, accuracy and reliability of the Telemetry Ground Station lends itself to reduction, analysis, and processing of magnetic tape recorded data from such programs as evaluation of Time-Division Data-Links, the AGACS system, ground and air-borne support equipment, communication programs, satellite and missile testing, and USW programs. The Telemetry Ground Station with minor additions, also may be used as a tracking station for direct reception of telemetered data from space vehicles.

For additional information on the skills and services available, contact the New Castle Engineering Facility.

ELECTROCHEMICAL SYSTEMS
. . . RCA Studies of Basic Properties Promise New High-Capacity Batteries

by **DR. G. S. LOZIER and R. J. RYAN**
Semiconductor and Materials Division, Somerville, N. J.

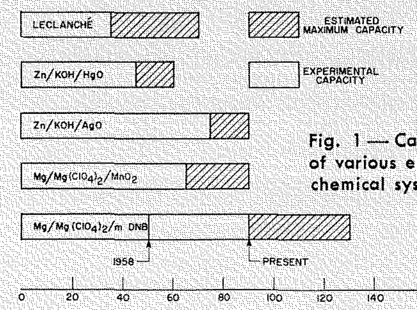


Fig. 1 — Capacity of various electrochemical systems.

IN THE United States, the battery industry has grown to its present $500 million volume because of the increasing need for portable electric-power sources. Many new developments demand batteries of high performance and reliability. To meet this demand, RCA has developed new electrochemical couples for primary and reserve cells.

ELECTROCHEMICAL CELL COMPONENTS

All electrochemical cells basically consist of an anode, a cathode, and an electrolyte. Chemically, anodes are reducing agents characterized by the relative ease with which they give up electrons to form positive ions, and cathodes are oxidizing agents characterized by the relative ease with which they accept electrons. The electrolyte acts as an electron barrier between the anode and cathode and permits electric current to flow by ionic conductance within the cell. The cell reaction can be expressed

Reducing Agent (Anode)
+
Oxidizing Agent (Cathode)
↓
Discharge Products

The discharge products consist of oxidized anode material and reduced cathode material.

Optimum Properties and Materials

Some optimum properties for anode and cathode materials for a practical battery system include:

1) High ampere-hour capacity C per unit weight and volume, as determined by Faraday's Law and expressed by $C = (F/M)\,n$, where F = Faraday constant, M = molecular weight, and n = electron change.
2) High electrode potential, determined by the free-energy change ΔG of the cell reaction, as expressed by $\Delta G = nFE$, where E is the electromotive force of the cell, and F is the Faraday constant (here, 23,060 calories).
3) Cell reaction having a high rate-constant or a low polarization during current flow.
4) High conversion efficiency of available chemical energy into usable electrical energy.
5) Reversible cell reaction.
6) Low temperature coefficient.

Data for items 1 and 2 are listed in Table I.

High-capacity electrochemical systems require high-capacity anode and cathode materials. However, when these materials are coupled to form a cell, they must be compatible with the electrolyte; the extent of compatibility depends upon the particular application.[1] For example, a cathode of silver (II) oxide and an anode of magnesium in acid solutions would not be practical because of the high solubility of silver oxide and the high rate of corrosion of magnesium in acid electrolytes.

Theoretically, the most desirable anode materials for dry and reserve cells are magnesium and aluminum; the most desirable cathode materials are the nitro-organic compounds: N-halogen organic compounds, silver (II) oxide, copper (II) oxide, and nickel oxide.

Emphasis of RCA Work

Major emphasis at RCA has been on the development of: 1) high-capacity primary cells with an organic cathode material, 2) magnesium primary cells with a perchlorate electrolyte, and 3) new high-performance secondary batteries for space applications. High-rate magnesium reserve cells having a perchlorate electrolyte can efficiently supply energy in less than thirty minutes. This type of cell has also been constructed with cupric-oxide and mercuric-oxide cathodes.

ORGANIC MATERIALS AS ACTIVE COMPONENTS IN PRIMARY CELLS

In practical application of organic materials to primary dry and reserve cells, many classes of compounds have been evaluated.[2, 3] The most promising for cathodes include: mono-nitro, di-nitro, tri-nitro compounds; C-nitroso compounds; and N-halogen compounds.

Recent work (under Signal Corps Contract DA-36-039-SC-78048) has demonstrated the feasibility of a magnesium-nitro organic primary cell. Such a magnesium dry cell, with an m-dinitrobenzene cathode and a magnesium-perchlorate electrolyte, has many performance characteristics superior to conventional primary systems, like zinc–ammonium-chloride, zinc-chloride–manganese-dioxide (LeClanche) cells.

DR. GERALD S. LOZIER received the B. S. in chemistry in 1952, the M. S. in chemistry in 1953, and the Ph. D. in 1956 from Western Reserve University, Cleveland, Ohio. From September 1950 until September 1952, he held a Teaching Fellowship at Western Reserve. For the next two years, he was engaged in research on the effects of ultrasonics on electrode processes at Western Reserve. In January 1955, he joined the RCA Laboratories, where he was engaged in research into new electrochemical systems. His investigations included primary- and secondary-battery systems, and fuel cells. In 1957, he received the *RCA Achievement Award* for outstanding research in electrochemical systems. In July 1959, he was transferred to the RCA Semiconductor and Materials Division in Somerville, N. J. As head of the group responsible for the development of both military and commercial systems, he has continued research on battery systems and fuel cells. Dr. Lozier is the author of 12 papers on battery systems and fuel cells, and is currently writing a book on the theory and application of batteries for the McGraw-Hill Publishing Company. He has been granted two patents. He is a member of the ACS and the Electrochemical Society.

ROBERT J. RYAN received the B. A. in Chemistry in 1952 from LaSalle College, Philadelphia, Pa., and is completing graduate work toward a M. S. in physical chemistry. From 1952 to 1956, he was employed by the Electric Storage Battery Company, Philadelphia, Pa. as a development engineer on lead-acid and nickel-cadmium storage battery systems and processes. In 1956 and 1957, he was supervisor in charge of nickel-cadmium battery design and development in the development division. In 1957, he joined the Chemical and Physical Laboratory of RCA at Camden, New Jersey and worked on investigations of N-halogen organic compounds for use as cathode materials in reserve batteries. He is presently employed in the field of Electrochemistry in the Semiconductor and Materials Division. He is a member of the ACS and the Electrochemical Society.

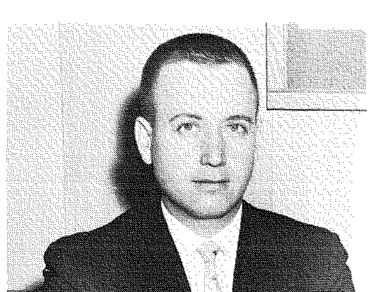
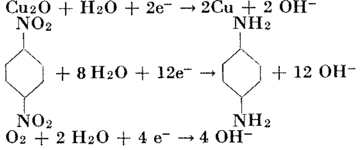


TABLE I—HALF-CELL REACTIONS, POTENTIALS, AND CAPACITY FOR VARIOUS ANODE AND CATHODES

Material	*Half-Cell Reactions*	*E,° Half-Cell Potential, Volts*	*Theoretical Capacity, Ampere-Hours* *Per lb*	*Per in³*
ANODE:				
*Pb	$Pb \rightarrow Pb^{++} + 2e$	0.13	117	47.5
	$Pb + SO_4^- \rightarrow PbSO_4 + 2e^-$	0.37	—	—
*Cd	$Cd + 2\ OH^- \rightarrow Cd(OH)_2 + 2e^-$	0.81†	216	67.0
*Zn	$Zn + 2\ OH^- \rightarrow Zn(OH)_2 + 2e^-$	1.245†	372	94.8
	$Zn \rightarrow Zn^{++} + 2e^-$	0.76	—	—
*Fe	$Fe + 2\ OH^- \rightarrow Fe(OH)_2 + 2e^-$	0.88†	435	122.9
*Mg	$Mg + 2\ OH^- \rightarrow Mg(OH)_2 + 2e^-$	2.67†	1000	62.1
	$Mg \rightarrow Mg^{++} + 2e^-$	2.37	—	—
Li	$Li \rightarrow Li^+ + e^-$	3.045	1752	33.2
Na	$Na \rightarrow Na^+ + e^-$	2.71	529	18.3
H	$H_2 \rightarrow 2H^+ + 2e^-$	0.00	12,062	30.2
	$H_2 + 2\ OH^- \rightarrow 2H_2O + 2e^-$	0.828†	—	—
CATHODE:				
*PbO₂	$PbO_2 + SO_4^- + 4H^+ + 2e \rightarrow PbSO_4 + 2H_2O$	1.685	101.8	33.8
*NiOOH₂	$2NiOOH_2 + 2H_2O + 2e^- \rightarrow 2Ni(OH)_2 + 2OH^-$	0.49†	243	29.7
*MnO₂	$MnO_2 + 4H^+ + 2e^- \rightarrow Mn^{++} + 2H_2O$	1.23	—	—
	$MnO_2 + H_2O^+ + e^- \rightarrow 1/2\ Mn_2O_3 \cdot H_2O + OH^-$	0.17†	140.6	25.1
*HgO	$HgO + H_2O + 2e^- \rightarrow Hg + 2\ OH^-$	0.098†	112	34.6
*AgO	$2AgO + H_2O + 2e^- \rightarrow Ag_2O + 2\ OH^-$	0.570†	198	52.1
*AgCl	$AgCl + e^- \rightarrow Ag + Cl^-$	0.222	85.1	16.9
*CuCl	$CuCl + e^- \rightarrow Cu + Cl^-$	0.137	126.9	15.9
*CuO	$2CuO + H_2O + 2e^- \rightarrow Cu_2O + 2\ OH^-$	0.159†	307	70.5
Cu₂O	$Cu_2O + H_2O + 2e^- \rightarrow 2Cu + 2\ OH^-$	0.357†	—	—
m-Dinitro-benzene		0.15†	874	49.0
O₂	$O_2 + 2\ H_2O + 4\ e^- \rightarrow 4\ OH^-$	—	1527.6	61.8

*Electrodes used in commercial batteries †E° base; other E° values are acid

TABLE II—CELL SIZES FOR TYPICAL TRANSISTORIZED TRANSCEIVER

For each cell in Figs. 5, 6. Transceiver using 10 volts at 0.1 ampere average for 20 hours.

Cell Type	*Battery lb*	*Size in³*
Mg-m-dinitrobenzene	0.33	6.6
Mg-MnO₂	0.45	5.7
Mg-CuO	0.50	5.7
Conventional LeClanche with synthetic MnO₂	1.25	10.0

TABLE III—PERFORMANCE OF RESERVE CELL SYSTEMS

Cells discharged under optimum conditions. (*RCA).

Type	*Ave. Oper. Voltage*	*w-hr/lb*	*w-hr/in³*
Zn-KOH-AgO	1.4–1.5	50–70	3.1–3.6
Mg-MgCl₂-AgCl	1.3–1.6	—	—
Mg-MgCl₂-CuCl	1.1–1.3	19–30	1.4
*Mg-Mg(ClO₄)₂-CuO	0.9–1.1	75	5.0
*Mg-Mg(ClO₄)₂-HgO	1.5–1.65	90	7.6
*Mg-MgBr₂-Trichloromelamine	1.9–2.3	70	3.0

The most outstanding property of the m-dinitrobenzene cell is its high experimental and estimated maximum-available capacity on a weight basis. A capacity of 90 w-hr/lb is obtained at useful discharge rates. The significance of this property can be seen in Fig. 1. The actual experimental capacity of the organic cell is equal to the maximum value theoretically attainable from other systems. The desirable flat voltage-time discharge characteristic of the magnesium–m-dinitrobenzene system is compared to that of an experimental high-capacity LeClanche cell in Fig. 2.

The magnesium–m-dinitrobenzene cell is adaptable to all conventional cell sizes and configurations. Preliminary data indicate good shelf-life; cells retained over 90 percent of capacity when stored at 70 ± 2°F and 50 ± 5-percent relative humidity for 15 months.

N-halogen compounds have also been used in reserve-type cells. Fig. 3 compares discharge data for an experimental magnesium – trichloromelamine battery and a comparable commercial magnesium–cuprous-chloride battery. On a weight and volume basis, the magnesium –trichloromelamine battery provided over twice the capacity of the magnesium–cuprous-chloride system. The magnesium–m-dinitrobenzene dry cell and the magnesium-trichloromelamine reserve cell are only two examples of the many types of primary cells which may be designed to use organic cathode materials.

Basic studies of electrode reactions indicate that when an organic cathode material is reduced, the active group (such as $-NO_2$, -NO, or $-NCl_2$) accepts electrons from the external circuit. A theory based on the distribution of the electron density in the molecule was developed to explain the relationship between the cathode potential and the type and position of substituted groups on the parent compound. This theory has been most fully developed for the aromatic mono- and di-nitro organic compounds and extended to the nitro hetero-cyclic compounds, nitroalkanes, and various organic anode materials. (See Fig. 4).

MAGNESIUM DRY CELLS

Research on basic properties of the magnesium anode has led to high-capacity magnesium primary cells, with a perchlorate electrolyte that has several desirable properties:

1) *Stable to strong oxidizing agents;* high-capacity materials such as silver (II) oxide and nickel oxide may be coupled to the magnesium anode.

2) *Does not complex as readily as a bromide electrolyte;* high-capacity cathode materials such as cupric oxide and mercuric oxide may be coupled to the magnesium anode.

3) *Improved anode efficiency under load (compared to a bromide-electrolyte);* capacity improvements up to 20 percent at medium and heavy current drains.

4) *Lower pH value;* higher cathode potentials in a perchlorate electrolyte than in a potassium hydroxide electrolyte.

The watt-hour capacities given in Figs. 5 and 6 are shown in a manner that normalizes the variation in operating voltage and current as a function of discharge rate. This method is used in presenting capacity data when determining the size of a battery for a given application (Table II).

Although satisfactory shelf-life data has been obtained from magnesium–magnesium-perchlorate dry cells made with cupric oxide and synthetic manganese dioxide, further development is needed in mercuric-oxide cells to give good storage characteristics. Fig. 2 included characteristic discharge curves for cupric-oxide and synthetic–manganese-dioxide cells having a magnesium-perchlorate electrolyte.

As a result of an oxide surface film, the magnesium anode has several inherent characteristics which affect its performance: a higher impedance than comparable-size LeClanche cells, a delay in voltage build-up when switched from light to heavy drain, and a drop in capacity at light and intermittent drains.

MAGNESIUM RESERVE CELLS

Reserve cells are primary cells assembled inactive and activated just

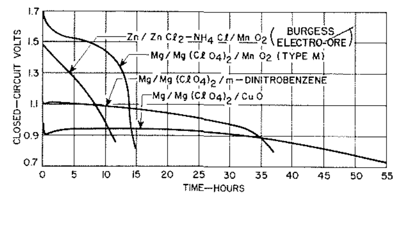


Fig. 2—Capacity for A-size dry cells discharged continuously through 16⅔ ohms.

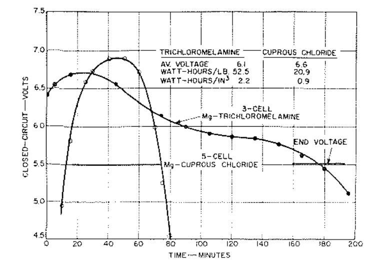


Fig. 3—Water-activated reserve batteries discharged continuosly through 12 ohms at room temperature.

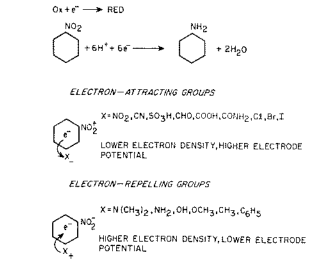


Fig. 4—Basic relationships between cathode potential of typical aromatic nitro compound and nature of substituent groups.

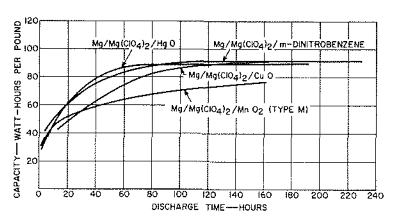


Fig. 5—Capacity per unit weight of dry cells vs. discharge time.

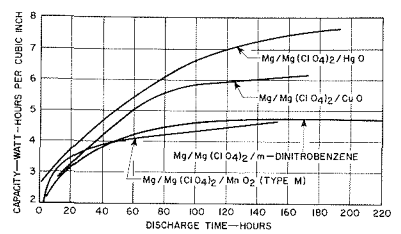


Fig. 6—Capacity per unit volume of dry cells vs. discharge time.

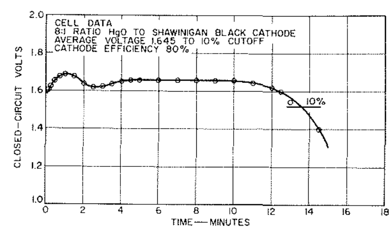


Fig. 7—Discharge characteristics of Mg-Mg $(ClO_4)_2$-HgO reserve cells at 10 amperes.

prior to use. They are designed to meet specific applications, as in guided missiles, rescue beacons, sonobuoys, and meteorology. Because of their construction, they may have inherent advantages over conventional primary batteries, such as more-active materials to obtain a high energy output per unit weight and volume at high current-discharge rates. They usually have a long unactiviated shelf-life, high reliability, and great design freedom.

Several of the electrochemical systems using a magnesium anode and a magnesium-perchlorate electrolyte offer definite promise for superior reserve cells. The magnesium–mercuric-oxide and cupric-oxide couples have been most extensively studied.

Reserve cells having these cathode materials differ from dry cells only in their manner of construction. Magnesium reserve cells are composed of multiple, thin, flat plates of magnesium; the cathode material is assembled in alternate fashion with a thin separator material between. This gives greater electrode surface area than corresponding round-type dry cells, increasing efficiency at high discharge rates.

Successful methods of making thin mercuric-oxide and cupric-oxide cathode plates for reserve cells have been developed. Table III compares RCA experimental reserve cells and existing commercial reserve systems, indicating the improved performance obtained with RCA systems. Data for an N-halogen organic reserve cell are also included.

Although Table III represents optimum results at low discharge rates, recent developments (under Signal Corps Contract DA-36-039-sc-85340) have shown these couples capable of high capacities on 5- to 30-minute discharge rates. A 10-ampere constant-current discharge of a magnesium–magnesium-perchlorate–mercuric-oxide cell is shown in Fig. 7. The capacity of this cell, with a voltage tolerance of $\pm$ 5 percent, is 43 w-hr/lb and 2.7 w-hr/in^3. Similar high rate-capacities have been obtained with the magnesium–cupric-oxide system.

In addition to capacity advantages, RCA cells have other desirable characteristics: 1) the cells can be activated under load, 2) the considerable heat generated during discharge aids low-temperature applications, 3) good activated stand can be achieved, 4) a non-corrosive electrolyte reduces handling problems, and 5) the cells have a low material cost.

Preliminary work on magnesium–magnesium-perchlorate reserve cells using silver-oxide and nickel-oxide cathode materials has indicated that practical cells with high capacity and high operating voltage can be achieved.

NEW RECHARGEABLE BATTERIES

RCA has recently initiated studies on the development of long-life light-weight secondary batteries for space applications. These investigations include new anode-cathode couples and their associated electrolytes and separators. The most promising couples have an anode selected from the low–molecular-weight alkali metals, alkaline-earth metals, or aluminum. The cathode is selected from the metal oxides having a high oxygen content or a metal-metal ion electrode. A molten-salt solvent system is the most promising electrolyte for the development of a secondary battery using the above anode materials.

A ceramic or porcelain membrane through which sodium or similar ions may pass reversibly is the best separator in molten-salt electrolytes. These materials can effectively prevent the mixing of the reactant materials; a porous separator can be used when the reactant materials have a low solubility in the molten-salt electrolyte.

SUMMARY

RCA has demonstrated several new electrochemical systems which promise development of high-capacity primary and secondary batteries. These systems have resulted from fundamental study of the basic electrochemical properties of high-capacity anode and cathode materials.

BIBLIOGRAPHY

1. G. S. Lozier, "Fuel Cells and Batteries", *RCA Review*, Vol. XXII, No. 2, June 1961.
2. C. K. Morehouse, R. Glicksman, and G. S. Lozier, "Batteries", *Proc. IRE* 46, 1462-1483, (1958). Reprinted, S. Levine, Ed., *New Techniques of Energy Conversion*, Dover Publications, Inc., New York (1961).
3. C. K. Morehouse, R. Glicksman, and G. S. Lozier, "Cells, Electric", *McGraw-Hill Encyclopedia of Chemical Technology*, 2nd Supplement, McGraw-Hill Book Co., N. Y., September 1960.

A SPECTROPHOTOMETER DIGITAL-OUTPUT SYSTEM

This system converts data from a recording spectrophotometer into digital form on punched cards, ready for computer processing. It eliminates the laborious manual translation of the chart recordings into computer input format. The system is solid-state throughout, and employs some novel magnetic circuits. Memory and some logic are combined by using the RCA-developed transfluxor.

by **D. HAMPEL**
Atomic Energy Services
RCA Service Co.
Cherry Hill, N. J.

OUTPUT INFORMATION from the unmodified Cary Model 14 Recording Spectrophotometer is in the form of a continuous chart recording of absorbency vs. wavelength. In data processing that requires statistical curve-fitting or spectrum-stripping, a computer must be used. The system described herein eliminates the costly and time-consuming method of manually transferring information from the chart recordings to the punched cards (or tape) required by the computer by electronically digitizing the analog signals from the spectrophotometer.

Extreme reliability of the digital system was a foremost system objective and dictated the use of magnetic devices wherever feasible. This led to some novel magnetic circuits well suited to the system. Commercial equipment was used wherever possible to keep development time and costs down.

The system was developed under the author's direction for the Analytical Chemistry Division of the Oak Ridge National Laboratories, USAEC, Oak Ridge, Tenn. The work was done under an RCA Service Co. contract with the Instrument Division, ORNL. The system is currently undergoing final checkout, and is planned for operational use in July 1961.

THE SPECTROPHOTOMETER

Radiation in the visible or ultraviolet region is generated and passed through an optical system which produces a monochromatic light beam of precisely known wavelength. This beam is passed through the chemical sample to be investigated and then to a photomultiplier and amplifier circuit. The electrical signal from this attenuated beam is compared with the signal from a "standard" beam; the difference signal, proportional to the absorbency of the sample, is recorded on a strip chart. As the strip chart moves, the wavelength is continually varied by a rotating prism in the optical system. The resulting pen trace is the absorbency spectrum of the sample.

The optical system can produce wavelengths in the range of 1850 to 26,000 angstroms with a resolution of 1 angstrom. A precision gear train couples the rotating member of the optical system to a mechanical counter which indicates the wavelength as the spectrum is being scanned. The scanning rate is variable in steps of 0.5 to 500 angstroms/sec. The chart speed can be varied in intervals from 1 to 8 inches/min. to facilitate accurate readings of absorbency. Thus, depending on the combination of wavelength scan rate and chart speed, the data can be displayed on the chart as from 1.25 to 1,000 angstroms/division.

The absorbency is recorded on a double scale across the chart; the first excursion of the pen across the entire width provides for a range of 0 to 1 absorbency units. For absorbencies in the range of 1 to 2 units, the pen returns to the zero position and traverses the chart once again. A marker in the margin of the chart indicates the scale range in use. Fig. 1 shows a sample spectrum produced by the instrument.

DIGITIZING SYSTEM

A block diagram of the system is shown in Fig. 2. Punched cards were used as the data medium rather than punched paper tape, for the following reasons: (1) by recording in decimal code on a standard printing punch, the output digital data can readily be inspected; (2) preliminary data reduction can be performed using punch-card peripheral equipment prior to computer processing; and (3) in the laboratory for which this system was built, more of the computers could accept punched-card information directly than punched tape information.

Digitized wavelength information is obtained in the form of electrical pulses from a photocell coupled to the mechanical register drive mechanism. An electrical pulse is generated for every angstrom unit traversed. These pulses feed a preset, cumulative electronic counter which in turn feeds the card punch. (This counter will be explained in detail in the following section.)

Digitized absorbency information is obtained from a slide-wire potentiometer coupled to the spectrophotometer strip-chart-recorder slide-wire drive mechanism. This transmitting potentiometer is energized with a precision voltage source (1.000 volt); the sliding tap feeds a digital voltmeter (DVM). Decimal output signals from the DVM are routed to the buffer and gating circuits for recording on the card punch.

Wavelength Counter

The characteristics required of this special purpose counter are:

1) must count in decimal, with a 5-digit capacity and in-line display;

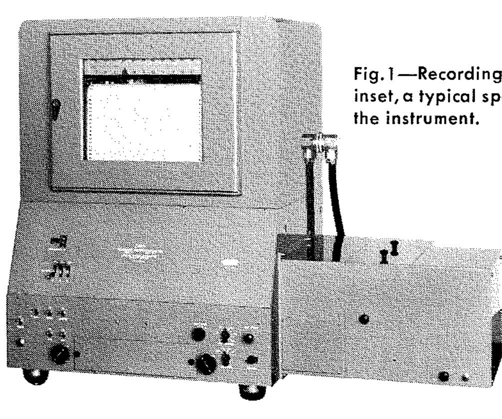
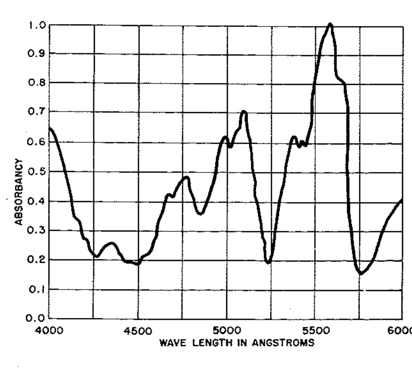


Fig. 1—Recording spectrophotometer; inset, a typical spectrum produced by the instrument.



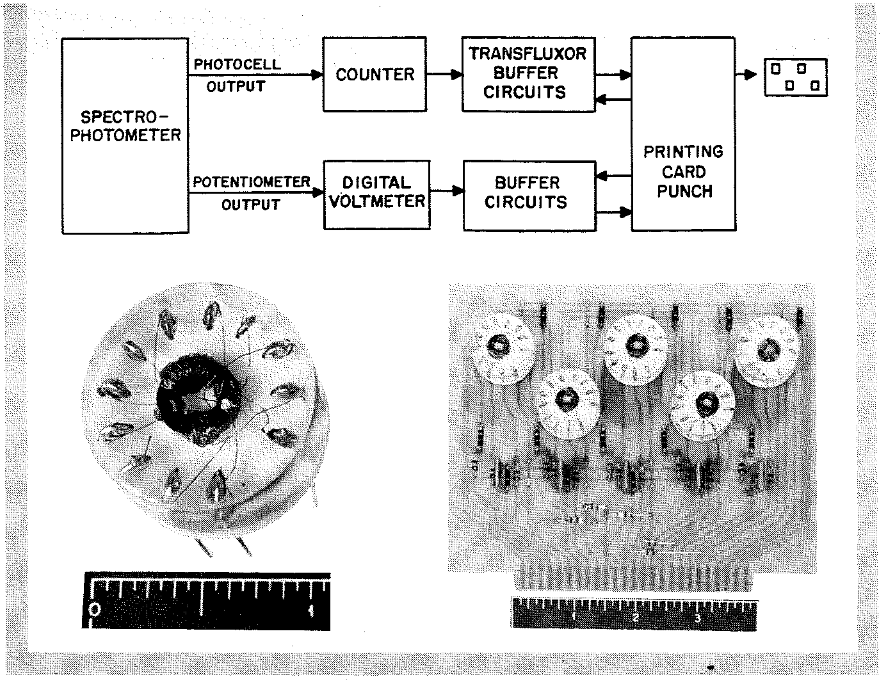
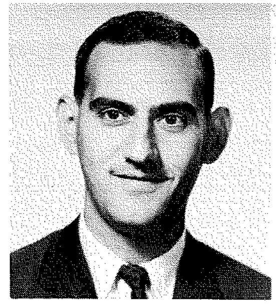


Fig. 2—Top: Digital output system diagram. Left photo: Transfluxor used for wavelength counter, potted in epoxy. Right photo: Transfluxor circuit board—two such boards are used for each decimal digit; associated components on board connect transfluxors to Nixie indicators, and silicon-controlled rectifier circuits, to energize card punch.



DANIEL HAMPEL received the BSEE in 1953 and the MSEE in 1958 from the Newark College of Engineering. He joined the Bell Telephone Laboratories as a member of the technical staff in 1953, and worked on electronic switching systems and circuits for the Electronic Central Office until 1957. He then joined the ITT Laboratories, working as a Senior Engineer in their Countermeasures Laboratory. He developed data-processing systems for radar and communications signals detection. He joined the RCA Service Co. in 1960 in Nuclear Engineering Services as a Project Engineer, and has worked on RCA Service Co. assignment to the Computer Engineering Section, Instrument Division, Oak Ridge National Laboratories, Oak Ridge, Tennessee. He is a member of Tau Beta Pi and Eta Kappa Nu, and during 1957-1960 was an evening school Instructor in Electrical Engineering at the Newark College of Engineering.

2) must have a buffer output stage so that counting may proceed while the card punch is recording the previous data point (the spectrophotometer does not stop traversing angstroms when a punch cycle is started);
3) must have isolated outputs for the punch;
4) must be able to insert any initial count (it is usually desired to start a spectrum at some given wavelength);
5) must be able to preset to a number of different wavelength intervals (it must provide an output signal to initiate a *record* cycle at either 1, 2, 5, 10, 20, 50, 100, 200, 500, or 1000 angstroms; the counter will trigger the record circuit every time the preset number of angstroms has passed);
6) must have high reliability and be insensitive to noise pulses generated by peripheral electrical equipment.

These characteristics were achieved by using magnetic-core ring counters driving transfluxor buffer circuits. The decade ring counters are commercially available, single-core-per-bit type which are easily preset by using simple *or* gates. Any initial count can be readily inserted. They have transistor outputs and are capable of supplying 40-ma, 8-μsec pulses. These pulses energize transfluxors[1,2] which have two minor apertures. One output circuit operates a transistor-driven Nixie indicator tube, while the other output is gated by contacts in the card punch to fire the silicon-controlled rectifiers (SCR) which operate the punch magnet relays.

Fig. 3 shows the transfluxor circuit. Its operation is as follows: The drive windings on all of the transfluxors (there are 10 per digit, a total of 50) are continuously energized with a 70-kc, 200-ma, peak-to-peak sine wave. If a transfluxor is in its *set* condition (one out of each group of 10 will always be set), each of the two isolated output windings will produce 2-volt-dc signals for their respective functions of firing an indicator circuit and an SCR. All those in the *reset* condition will produce approximately 0.1-volt-dc signals.

Fig. 4 is a skeleton circuit showing the connection of the counter to the transfluxors. As a pulse comes from Output 1, it sets transfluxor 1 and resets transfluxor 0. Indicator 1 comes on, and number 1 is available for punching, if a punch cycle had been initiated and if it is the units-digit position to be punched (as determined by gating contacts within the punch). If another input pulse comes along, output 2 from the ring counter gets a pulse. This sets transfluxor 2 and resets transfluxor 1, etc.

When a punch cycle is started, the gate shown is closed. This prevents currents

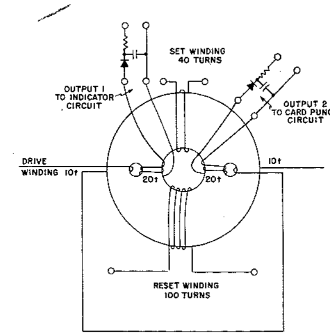


Fig. 3—Transfluxor circuit.

from flowing into the transfluxor *set* and *reset* windings, but does not hinder the operation of the ring counter. The transfluxors maintain their count until the card punch has recorded all the digits. The gate then opens, and all transfluxors are cleared. (The clearing circuit is not shown in Fig. 4.) The next time the ring counter is energized, the new output automatically registers the latest state of the counter in the appropriate transfluxor.

The transfluxors were custom-made and potted at the Oak Ridge National Laboratory. A standard commercial 0.375-O.D. square-hysteresis-loop ferrite core was used. (Holes in the pattern shown in Fig. 3 were drilled by ultrasonics; all windings are of 38 gauge wire.)

Absorbency Digitizing

The decision to use an Epsco high speed, all-transistorized digital voltmeter (DVM) for analog-to-digital conversion made the design problems of this part of the system rather simple. (Any four-digit DVM with decimal output and a maximum conversion time of 0.2 second could be used.) It was necessary to add a set of transistor amplifiers to boost the weak signal from the decimal outputs of the DVM, and to have them drive isolated coupling circuits to the punch. An in-line projection display and the storage feature were already part of the instrument. When a punch cycle is started, the DVM is triggered to sample the voltage on the potentiometer. This digitized voltage is available in 10 msec and remains there until the DVM is triggered for the next data point.

Coupling pulse transformers were added to the outputs of the transistor

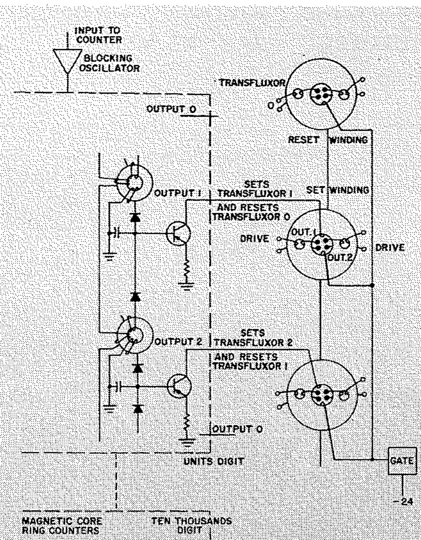


Fig. 4—Connection of magnetic-core ring counter to transfluxors (clearing circuit not shown).

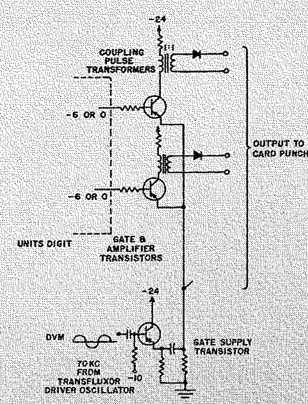


Fig. 5—DVM output circuit.

amplifiers to make their output signals compatible with those of the transfluxors. These signals energize the silicon-controlled rectifiers and are gated sequentially by contacts in the punch. A skeleton circuit is shown in Fig. 5. Only one of each group of ten output leads (for the units, tens, and hundreds digits) is at −6 volts, all others being at 0 volts. Thus, the 70-kc gate supply only gets through the one coupling pulse transformer, making it compatible with outputs from the counter. (The circuits following this are explained in the next section.)

The DVM has an overflow digit indicator which normally reads 0 as the output absorbency ranges from 0.000 to 0.999. When the spectrophotometer changes absorbency ranges from 0 to 1 to 1 to 2, a signal then causes the overflow to read 1. The potentiometer output again traverses voltages from 0 to 1 volt, but now the recorded absorbency on the punch is 1.000 to 1.999. Thus, 4-digit accuracy is maintained with this 3-digit instrument. The basic accuracy of the instrument is ±1 digit in the least-significant place.

Output Circuits to the Card Punch

The punch used is equipped with a *Read-in, read-out* device. That is, all internal control leads necessary for automatic operation of the punch are brought out to a plug for the external connections. This eliminates the need for going into the machine and making connections. In addition, an auxiliary-program card drum is provided, synchronized with the main-program drum and the card being punched. This provides contacts for the sequential connection (column by column) of the appropriate external circuits to the silicon-controlled rectifiers, which in turn operate the punch magnet control relays. Explanation of the card format will clarify the punch operation:

For each *record* cycle, the following digits will be punched: 1) 5-digit wavelength number, 2) 4-digit absorbency number, and 3) 1 space. This will repeat 7 times on each card, resulting in 10 remaining columns. After the last data point is punched, the card will skip columns 69 through 77 and then punch a preset *run* number on columns 78, 79, and 80. After this sequence, the card passes through, and the next card automatically takes its position under the punch head, ready to accept the following 7 data points.

Fig. 6 shows the output circuits. The card on the auxiliary drum is prepunched with a pattern of holes to correspond with the desired card format. For example, there is a hole in column 1 and in position 1. This hole connects all of the 10 *ten-thousands*-digit output circuits from the transfluxors to the 10 SCR's. Whenever a punch cycle is initiated, only the energized transfluxor output winding will fire that particular circuit. Although there are 8 other output circuits multiplied to each SCR, they belong to digits which are not connected at that time. The card then moves to Column 2, but the auxiliary drum card now has a hole only in Position 2. This connects the 10 *thousands*-digit output circuit to the SCR's, etc.

Finally, at Column 9, the units digit of the DVM output is given access to the SCR's. After this punch, the card automatically skips a space (as determined by the main program card pattern) and comes to rest at Column 11, ready for the next data point when a punch signal is obtained from the preset circuit of the counter.

The recent availability of the silicon controlled rectifier, a solid-state equivalent of the thyratron, has greatly improved the reliability of the punch drive circuits. The SCR's used here can supply 200-volt signals at 1 ampere in response to a 2-ma drive signal. The SCR's are extinguished by a column-synchronized cam contact internal to the punch. A momentary circuit break at the common cathode point stops the *on* rectifier from conducting.

SYSTEM OPERATION

The limiting speed of the system is the time required for a card to enter the punch station from the input hopper after Data Point 7 is punched. One second was allowed for this function. (The time to punch the 9 columns and a space for Data Points 1 through 6 is about 0.3 seconds.) Hence, the spectrophotometer scanning rate in angstroms per second must be less than or equal to the wavelength interval for punching. For example, if it is desired to take readings at every 10 angstroms, the scan rate must be 10 angstroms/sec or slower. Assume, in this example, that the initial wavelength was set at 500 angstroms and that it is desired to obtain the spectrum up to 10,000 angstroms in the shortest possible time. After the proper *clear* and *set* switches have been operated and the unit started, the time and number of cards produced will be:

$$\frac{10{,}000 - 500 \text{ angstroms}}{10 \text{ angstroms (intervals)}} = 950 \text{ data points}$$

At 7 data points per card, 136 cards will be punched in 950/60 = 36 minutes (approximately).

The system is flexible in that the card format is easily altered by changing the auxiliary drum program card in the machine. Furthermore, the unit is readily adaptable to data punching at a fixed wavelength and at different pressures or temperatures at different time intervals. This is done by using the counter as a preset timer (or digital clock) and by triggering it with accurately spaced pulses from a clock mechanism or oscillator.

THE TRANSFLUXOR

A brief discussion of the theory for the particular transfluxor type which was made use of in the system is presented. (It is recommended that the References 1 and 2 be referred to for a more comprehensive treatment.)

Basic Transfluxor Principles

Consider a standard ferrite square hysteresis loop magnetic core as shown in Fig. 7, with a hole drilled out much smaller than the core's inside diameter. The characteristics or function of the core are hardly disturbed, considering

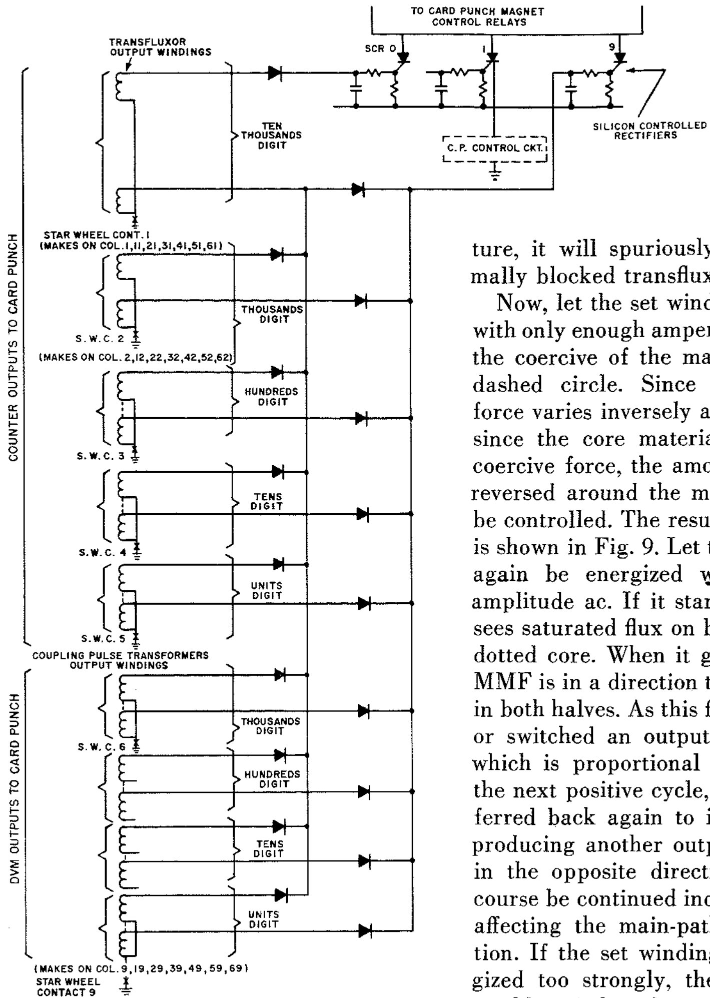


Fig. 6—Coupling circuits to card punch.

its main aperture; that is, almost all the flux is either clockwise or counterclockwise, depending on whether a current pulse of sufficient amplitude and duration had most recently energized the reset or set winding respectively.

Now, assume all the flux is clockwise and that a drive winding linking the small aperture is energized with ac, as shown in Fig. 8. Assume, also, that the peak driving magnetizing force is greater than the coercive force of the material only within the dotted circle and less than the coercive force outside this circle. When the drive is positive, it will apply an effective MMF in a clockwise sense around the dotted material or "subcore." Since the right-hand leg of this material is already in a saturated condition, there can be no flux transfer in the loop, since magnetic flux flow is necessarily in closed paths. When the drive is negative, the saturation in the left half of the dotted core blocks any flux change. Thus the transfluxor is "blocked," and there is little or no output observed on the output winding. The a-c drive must be limited in amplitude, for if it produces an MMF large enough to affect the flux around the main aperture, it will spuriously unblock a normally blocked transfluxor.

Now, let the set winding be energized with only enough ampere-turns to exceed the coercive of the material within the dashed circle. Since the magnetizing force varies inversely as the radius, and since the core material has a definite coercive force, the amount of flux to be reversed around the main aperture can be controlled. The resulting flux pattern is shown in Fig. 9. Let the drive winding again be energized with the limited-amplitude ac. If it starts off positive, it sees saturated flux on both halves of the dotted core. When it goes negative, the MMF is in a direction to reverse the flux in both halves. As this flux is transferred or switched an output voltage appears which is proportional to $\Delta\phi/\Delta t$. Upon the next positive cycle, the flux is transferred back again to its original state, producing another output voltage pulse in the opposite direction. This can of course be continued indefinitely, without affecting the main-path flux configuration. If the set winding had been energized too strongly, the small aperture would again have been in a blocked state, since the drive winding would encounter saturated flux for either polarity.

The device can be thought of as a flip-flop. It accepts a pulse to set or reset (the turns must be different if the pulse amplitudes are equal) and it provides a continuous output (ac, or dc if rectified). If the drive supply is turned off, the transfluxor does not forget its last state and will continue in its same state when driver power is returned and until a new set or reset pulse comes.

Transfluxor Used in the System Counter

Fig. 10 shows the configuration of the transfluxor used in the counter of the digital system described herein. Both minor apertures act alike: they are both either blocked or unblocked. Theoretically there can be any number of independent apertures as long as their flux paths do not interact, and as long as the main aperture characteristics are not impaired. The primary reason for using two apertures in this application was that two isolated output circuits were required. For the core which was used, one small aperture isn't large enough to contain all the necessary windings. The largest presently available commercial transfluxors, built by RCA, is shown compared to the fabricated model in Fig. 11. Its minor aperture is still smaller than those of the fabricated transfluxor. These units and even smaller ones are ideally suited for driving low-impedance, low-power circuits, where the number of turns can be kept down.

BIBLIOGRAPHY

1. Dr. J. A. Rajchman and A. E. Lo, *Proceedings of the IRE*, March, 1956, p. 321-332.
2. Dr. J. A. Rajchman, "The Transfluxor," RCA Engineer, Vol. 2 No. 3, Oct.-Nov. 1956.

ACKNOWLEDGEMENT

Credit is due to the following members of the Oak Ridge National Laboratory: To Dr. R. E. Biggers of the Analytical Chemistry Division for presenting the system requirements and for aiding in the determination of the system philosophy, to J. W. Woody, Jr. of the Instrumentation and Controls Division for his contribution to the design of many of the circuits and components; to D. L. Ramsey, also of the Instrumentation and Controls Division, for much of the mechanical design of the transfluxors, and to B. J. Moore, for helping in the final system testing and de-bugging.

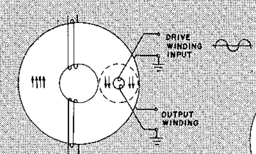


Fig. 8

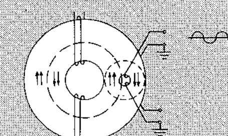


Fig. 9

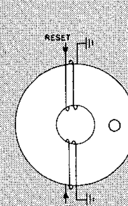


Fig. 7

Figs. 7, 8, 9—Basic transfluxor principles (see text).

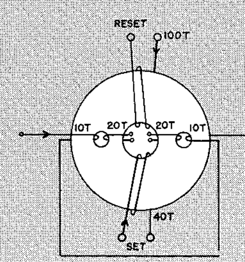
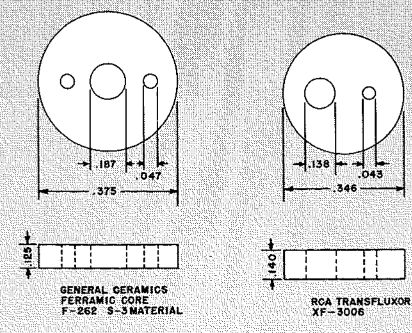
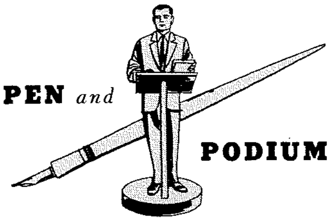


Fig. 10—Left: Custom-made transfluxors used in the spectrophotometer digital-output system.

Fig. 11—Below: Largest commercial transfluxor presently available (RCA XF 3006).





BASED ON REPORTS RECEIVED OVER A PERIOD OF ABOUT TWO MONTHS

INDUSTRIAL ELECTRONIC PRODUCTS

Abstracts of the Algorithms—Telescope 1 & Telescope 2
K. A. Brons: Algorithm Dept. of *Communication of the ACM,* March 1961

Analytical Verification of the Performance of a Tapered Co-Axial Load for UHF Television
R. H. Regimbal: *Thesis,* University of Penn, February, 1961

Theory and Application of Ampliphase Modulation
D. R. Munson: Western Association of Broadcasters Engineers Convention, February, 1961

A Report on Significant Numbering Systems
D. C. Bowen: AOA Documentation Section, New Orleans, La., March, 1961

The Impact of Electronic Computers on Our Everyday Life—Today and Tomorrow
R. E. Montijo: Southern Arizona AFCEA Chapter, March, 1961

Electronic Data Processing by Transistors and Tunnel Diodes
J. H. Sweer: Business Research Conference, Roosevelt University, Chicago, March 29, 1961

New Camera Tubes and Cameras
J. H. Roe: SMPTE Meeting, Washington, D. C., April 17, 1961

Acoustical Considerations
J. E. Volkmann: Architect and Engineer's Seminar, Harrisburg, Pa., April 17, 1961

ELECTRON TUBE DIVISION

Measurement of Composition and Thickness of Iron-Nickel Films By X-Ray Fluorescence Techniques
A. Month, M. Schindler, and J. Antalec: Conference on Analytical Chemistry and Applied Spectroscopy, Pittsburgh, Pa., March 3, 1961

A New Method of Magnetron Tuning and Frequency Stabilization
R. M. Salzer, R. Steinhoff: IRE International Convention, New York City, March 21, 1961

Electron-Tube Deterioration Utilizing Kinetic Theory
E. R. Schrader: MIT Physical Electronics Conference, Cambridge, Mass., March 29, 1961

A Computer Program for the Analysis of Triode Life-Test Data
A. G. F. Dingwall: MIT Physical Electronics Conference, Cambridge, Mass., March 29, 1961

An Analysis of the Factors Affecting Sublimation During Receiving-Tube Cathode Processing
V. Raag: MIT Physical Electronics Conference, Cambridge, Mass., March 29, 1961

90-Watt Five-Band Transmitter
G. D. Hanchett: *QST,* March, 1961

Effect on Height-to-Diameter Shrinkage Ratio on Dimensional Control of Dry-Pressed Ceramics
L. P. Garvey: American Ceramic Society Meeting, Toronto, Canada, April 23-27, 1961

Triode-Connected Beam Tubes as Linear Amplifiers
H. C. Vance, Dayton Hamvention, Dayton, Ohio, April 29, 1961

The Transidip
L. W. Aurick: *Popular Electronics,* April, 1961

Peaceful Uses of Radioactive Materials
H. A. Stern: Beth-El Mens Club, Lancaster, Pa., March 5, 1961

Gas-Phase Proportional Counting—A Radiotracer Technique for Examining Electronic Devices and Materials
H. A. Stern: ASTM Symposium on Materials for Electron-Device Processing, Philadelphia, Pa., April 5-7, 1961

Sulfamic Acid Cleaning of Electron-Tube Parts
R. W. Etter: ASTM Symposium on Materials for Electron-Device Processing, Philadelphia, Pa., April 5-7, 1961

New Television Camera Tubes for Use With Fiber Optic Devices
P. W. Kaseman: Council on Medical TV, National Institute of Health, Bethesda, Md., April 6, 1961

The Use of Radioactive Isotopes in Industry
H. A. Stern: Cornell-Lebanon Surburban Joint School System, Pa., April 11, 1961

Evaluation of Ceramics for Ceramic-to-Metal Seals
M. Berg and J. A. Zollman: American Ceramic Society Meeting, Toronto, Canada, April 23-27, 1961

Ceramic Enclosures for Semiconductor Devices
M. Berg and F. Hinnenkamp: American Ceramic Society Meeting, Toronto, Canada, April 23-27, 1961

Performance of Vidicons Under Unusual Environmental Conditions
G. A. Robinson: *Journal of SMPTE,* April 1961

A New Microwave Parametric Amplifier
C. L. Cuccia: *Electronic Products,* April 1961

Picture-Tube Improvements Through Controlled Environment and Ultrasonic Techniques
J. C. Halbrook: IRE International Convention, New York City, March 20, 1961

Two Photoconductive Detectors for Space Applications
M. L. Schultz, W. E. Hart and G. A. Morton: 5th National Infrared Information Symposium, San Francisco, Calif., April 27-27, 1961

Tunnel-Diode Microwave Oscillators
F. Sterzer and D. E. Nelson: *Proceedings of the IRE,* April 1961

SEMICONDUCTOR AND MATERIALS DIVISION

Transistor Concepts and Fabrication Problems
A. Mohr: AIEE Lehigh Valley Section Meeting, Wilkes-Barre, Pa., April 20, 1961

Preparation and Properties of low-loss Ferrites
A. P. Greifer, Y. Nakada, and H. Lessoff: *Journal of Applied Physics,* March 1961

Ferrite Thin Films
H. P. Lemaire and W. J. Croft: *Journal of Applied Physics,* March 1961

Tunnel Diodes
A. Blicher: Electrochemical Society Metropolitan Section Meeting, Newark, N. J., March 1, 1961

Materials and Form Factors for Micromodule Inductors
G. G. Hauser: IRE International Convention, New York City, March 22, 1961

Semiconductor Devices—Their Status and Future
E. O. Johnson: IRE International Convention, New York City, March 21, 1961 and IRE Section Meeting, Cincinnati, Ohio, April 13, 1961

Micromodule Reliability Status Report
D. T. Levy: IRE International Convention, New York City, March 22, 1961

Solution-Grown Epitaxial Layers on Germanium
E. A. Lederer: MIT Physical Electronics Conference, Cambridge, Mass., March 27, 1961

Effect of Cold-Working and Recrystalization on the Annealing-Out of Vacancies in a AG-ZN Alloy
A. E. Roswell: AIME Annual Meeting, St. Louis, Mo., March 1961

Transistor Equivalent Circuits
J. Hilibrand: IRE Section Meeting, Rochester, N. Y., April 3, 1961

The Effects of Various Cleaning Methods on Electronic Components in the Micromodule
J. L. Vossen: ASTM Symposium on Materials for Electron-Device Processing, Philadelphia, Pa., April 4-6, 1961

A Transistorized Stereo Amplifier
C. F. Wheatley: Audio Engineering Society Meeting, Los Angeles, Calif., April 7, 1961

Gallium Arsenide Solar Energy Converters
D. Bortfeld, M. Lamorte, G. McIver and A. Gobat: IRE Section Meeting, Cincinnati, Ohio, April 18, 1961

Absorption Edge in Degenerate P-Type GaAs
I. Kudman and T. Seidel: American Physical Society Meeting, Washington, D. C., April 20-24, 1961

Investigation of the Electrochemical Characteristics of Organic Compounds—VII. Organic Positive Iodine and Aliphatic AzO Compounds
C. K. Morehouse and R. Glicksman: *Journal of Electrochemical Society,* April 1961

High-Speed Logic Using Low-Cost Mesa Transistors
R. D. Lohman, R. R. Painter, D. R. Gipp, and B. Zuk: *Semiconductor Products,* April 1961

RCA VICTOR RECORD DIVISION

Toscanini and Stereo
J. A. Somer: *High Fidelity,* March 1961

DEFENSE ELECTRONIC PRODUCTS

Switching Time of Tunnel Diode
O. S. Goda: IRE Professional Group on Electronic Computers, Van Nuys, March 16, 1961

Tunnel Diodes for Computers
J. A. Cornell: IRE Professional Group on Electronic Computers, Van Nuys, March 16, 1961

Practical Approach to Cost Analysis
B. B. Katz: Air Force Contracting Officer's School, Dayton, Ohio, April 17, 1961

Reliability and Quality Control
S. Nozick: IRE International Convention, New York City, March 22, 1961

Management Insight Into Your Publications Future
S. Hersh: 8th Annual Convention, Society of Technical Writers and Publishers.

Elementary Satellite Thermal Problems
G. D. Gordon: American Assoc. of Physics Teachers, New York City, February 2, 1961

Synchronous vs. Low-Level Distributed Satellite Communication Systems
H. R. Mathwich: AIEE Technical Session on Space Communication, New York, February 1, 1961

Automatic Syntax Analysis in Machine Indexing and Abstracting
W. D. Climenson, S. N. Jacobson, N. H. Hardwich: American University, 3rd Institute on Information Storage and Retrieval, Washington, D. C., March 6, 1961

A New Digital Tape Editing System for Television
W. J. Haneman and H. Ostrow: SMPTE, 89th Convention, Toronto, Canada, May 11, 1961

Television Cameras in Space
M. H. Mesner: SMPTE, New York, March 8, 1961

Transport of Electric Charge Through Organic Polymer Films
J. J. Spokas: Polytechnic Institute of Brooklyn, Brooklyn, N. Y., March 25, 1961

DATES and DEADLINES

PROFESSIONAL MEETINGS AND CALLS FOR PAPERS

MEETINGS

Aug. 22-25, 1961: WESTERN ELEC. SHOW & CONF.; (WESCON) IRE, WEMA; Cow Palace, San Francisco, Calif. *Prog. Info.:* E. W. Herold, c/o WESCON No. Calif. Office, 701 Welch Rd., Palo Alto, Calif.

Sept. 6-8, 1961: NATL. SYMP. ON SPACE ELEC. & TELEMETRY; IRE-PGSET; Albuquerque, N. M. *Prog. Info.:* Dr. B. L. Basore, 2405 Parsifal N. E, Albuquerque, N. M.

Sept. 6-13, 1961: INTL. CONF. ON ELEC. ENG. EDUCATION; ASEE, IRE-PGE, AIEE, Syracuse Univ.; Sagamore Conf. Center, Syracuse Univ., Adirondacks, N. Y. *Prog. Info.:* Dr. W. R. LePage, Syracuse Univ., Syracuse, N. Y.

Sept. 13-14, 1961: CONF. ON TECHNICAL-SCIENTIFIC COMMUNICATIONS; IRE-PGEWS; Bellevue-Stratford, Phila., Pa. *Prog. Info.:* E. R. Jennings, RCA, Bldg. 2-8, Camden.

Sept. 14-15, 1961: 9TH ANN. ENGINEERING MANAGEMENT CONF.; IRE-PGEM, AIEE, et al. *Prog. Info.:* H. M. O'Bryan, GTE Labs, 730 Third St., New York, N. Y.

CALLS FOR PAPERS:

Oct. 16-17, 1961: EAST LANSING SYMPOSIUM ON ENGINEERING WRITING AND SPEECH, IRE-PGEWS, Kellog Center, Michigan State Univ., East Lansing, Mich. *DEADLINE:* 500-wd. abstracts, **7/15/61** to J. D. Chapline, Philco Corp., 3900 Welsh Rd., Willow Grove, Pa.

Oct. 26-28, 1961: 1961 ELECTRON DEVICES MTG., IRE-PGED, Sheraton-Park Hotel, Wash., D. C. *DEADLINE:* Abstracts, **8/1/61** to Dr. I. M. Ross, Bell Telephone Labs, Rm. 2A-329, Murray Hill, N. J.

Nov. 6-8, 1961: Spec. Technical Conf. on Non-Linear Magnetics, IRE-PGEC, PGIE; AIEE, Statler-Hilton Hotel, L. A., Calif. *DEADLINE:* Papers, **8/1/61** to Dr. T. Bernstein, Space Technology Lab., P. O. Box 95001, L. A. 45, Calif.

Nov. 13-16, 1961: CONFERENCE ON MAGNETISM AND MAGNETIC MATERIALS; IRE; Hotel Westward Ho, Phoenix, Arizona. *DEADLINE:* 500-wd. abstracts, **8/18/61** to F. E. Luborsky, GE Research Lab., PO Box 1088, Schenectady, N. Y.

Feb. 7-9, 1962: THIRD WINTER CONVENTION ON MILITARY ELECTRONICS, Ambassador Hotel, Los Angeles, Calif. IRE-PGMIL; *DEADLINE:* Abstracts, **8/1/61** to IRE L. A. Office, 1435 S. La Cienaga Blvd., L. A., Calif.

Feb. 14-16, 1962: 1962 INTL. SOLID-STATE CIRCUITS CONF.; IRE, AIEE, Univ. of Penna.; Sheraton Hotel and Univ. of Penna., Philadelphia, Pa. *DEADLINE:* 300-500 wd. abstracts, **11/1/61** to R. H. Baker, Rm. C-237, MIT Lincoln Lab., Lexington, Mass.

Mar. 26-29, 1962: THE 1962 IRE INTERNATIONAL CONVENTION; Waldorf Astoria and N. Y. Coliseum, New York City. *DEADLINE:* (3 cys. each, 100-wd. abstract and 500-wd. summary) **10/20/61,** to Dr. D. B. Sinclair, IRE Inc., 1 East 79th Street, New York 21, N. Y.

April 1962: SOUTHWEST IRE CONF. & ELEC. SHOW (SWIRECO), Rice Hotel, Houston, Tex. *DEADLINE:* Author and title of paper, **10/1/61;** abstract, **12/1/61** to Professor M. Graham, Rice Univ., Computer Project, Houston 1, Tex.

May 8-10, 1962: ELECTRONIC COMPONENTS CONF.; IRE-PGCP, AIEE, EIA, WEMA; Washington, D. C. *DEADLINE:* 15 cys., 500-wd. abstract, **10/9/61** to H. Stone, Bell Telephone Lab., Murray Hill, N. J.

May 14-16, 1962: NATL. AEROSPACE ELECTRONICS CONF. (NAECON); IRE-PGANE, Dayton, O. *DEADLINE:* Abstracts, **1/5/62** to R. Nordlund, NAECON, 1414 E. Third, Dayton, O.

June 25-30, 1962: SYMPOSIUM ON ELECTROMAGNETIC THEORY AND ANTENNAS; The Technical University of Denmark, Oster Voldgarde 10G, Copenhagen K., Denmark. *DEADLINE:* 1200-wd. summaries, **12/1/61,** to H. Lottrup Knudsen, above address. (USSR expected to undertake two sessions.)

Aug. 27-Sept. 1, 1962: 1962 CONGRESS, INTL. FEDERATION OF INFORMATION PROCESSING SOCIETIES (IFIPS); incl. IRE, ACM, AIEE; Munich, Germany. *DEADLINE:* 500-1000 wd. abstracts, **9/15/61;** complete ms. **3/1/62;** to Dr. E. L. Harder, Westinghouse Electric Corp., East Pittsburgh, Pa.

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

Engineering Description of Data Transmission System for TIROS
J. A. Strother: COSPAR Session on Telemetry and Data Recovery, Florence, Italy, April 12, 1961

The Weighted Resistor Decoder: An Error Analysis
N. Aron and R. Goundry: *Electro-Technology*, April 1961

Step-By-Step Design of Phantastron Circuits
M. J. Levin: *Electronic Design*, May 10, 1961

A Method for the Complete Description of Infrared Background
H. Eldering: *Journal of the Optical Society of America*, Pittsburgh, Pa., March 3, 1961

Micromodules in Avionics—Applicable, Practical
G. Sievers and M. DiBartolomeis: *IRE Proceedings* and International Convention, March 23, 1961

A Servo Model for Use in Engineering Project Management
R. B. Wilcox and C. M. King: AIEE, Boston, April 4, 1961

A Multi-Mode System
H. Eldering: Infrared Information Symposium, San Francisco, April 27, 1961

A Terminal Guidance Law Which Achieves Collision Based on Coriolis Balance Techniques
M. L. Nason: American Astronautical Society, Dallas, Texas, January 18, 1961 and Proceedings, January 1961

RCA Module Analyzer
W. Mergner and J. A. Paschall: *Electronics*, April 21, 1961

Fast Recovery Diodes Simplify Pulse Shaping Circuit
R. E. Hartwell: *Electronic Design News*, May 1961

The Programming of Automatic Test Equipment
E. D. Wyant: *Master's Thesis*, University of Pennsylvania

Design Considerations for an Automated Depot
J. M. Laskey and D. B. Dobson: NAECON 1961, Dayton, Ohio, May 8-10, 1961

Transient Ablation and Heat Conduction Phenomena at a Vaporizing Surface
R. G. Fleddermann and H. Hurwicz: Chemical Engineering Progress Symposium Series, March 1961

The Disciplined Geometry of Micro-Modules Yields Practical Miniaturization
J. W. Knoll: National Aviation Meeting of the American Society of Mechanical Engineers, Los Angeles, March 1961

Semiconductor Bandpass Filters
J. J. Sein and S. N. Levine: IRE International Convention, New York, March 22, 1961, *IRE International Record*

Science or Engineering
S. P. Shackleton: *National Vocational Guidance Association Quarterly*

Prediction of Spurious Levels in Transmitting Equipment
J. G. Arnold: *Electronics*

The Design and Application of Dry Reed Relays to an Electronic Switching System
J. C. Dietz and J. Swyler: National Conference on Electro-Magnetic Relays, Oklahoma State University, April 25, 1961

Air Lubrication—A Development Tool
M. L. Levine: Lubrication Symposium, Miami, Florida, May 8, 1961

RCA LABORATORIES

The World of Electronics
H. L. Cooke: Kiwanis Club, Ewing Township, Trenton, N. J., February 23, 1961, and N. J. Vocational & Arts Association, Asbury Park, N. J., March 10, 1961

Electron-Hole Plasmas in Semiconductors—Self Pinching and Oscillations
M. Glicksman: American Physical Society, Monterey, Calif., March 20-23, 1961

Thermal Conductivity in Semiconductors at High Temperature
B. Abeles: American Physical Society, Monterey, Calif., March 20-23, 1961

Carrier Transport and Scattering in $AgSbTe_2$
A. Amith: American Physical Society, Monterey, Calif., March 20-23, 1961

Photoconductivity of GaAs: Si:Cu Crystals
R. H. Bube and J. Blanc: American Physical Society, Monterey, Calif., March 20-23, 1961

The Production of Pairs in Semiconductors By Low Energy Electrons
W. E. Spicer: American Physical Society, Monterey, Calif., March 20-23, 1961

Resistance Anomaly in B-Tungsten Compounds
G. Cody, J. Hanak and G. McConville: American Physical Society, Monterey, Calif., March 20-23, 1961

Multicomponent Magnetoplasma Resonance in Germanium
B. Rosenblum and R. E. Michel: American Physical Society, Monterey, Calif., March 20-23, 1961

Transport Studies in Germanium by Cyclotron Resonance Techniques
R. E. Michel and B. Rosenblum: American Physical Society, Monterey, Calif., March 20-23, 1961

Oscillations in Semiconductor Plasmas
M. Glicksman: American Physical Society, Monterey, Calif., March 20-23, 1961

Warm Electrons Measurements in n-Type Germanium
D. Meyerhofer and S. Bermon: American Physical Society, Monterey, Calif., March 20-23, 1961

The Measurement of Internal Physiological Phenomena Using Passive-Type Telemetering Capsules
V. K. Zworykin, F. Hatke (and outside authors): IRE International Convention, March 21, 1961

Gallium-Phosphorus-Silicon-Zinc Quarternary System and Analogs
E. E. Loebner: Symp. of the ACS on The Chemistry of Semiconductors, March 28, 1961

Faraday Rotation in Semiconductors
M. Cardona: German Physical Society Meeting, Bad Pyramont, April 1961

The Preparation and Properties of Some Hexagonal Magnetic Oxides
I. Gordon, R. L. Harvey and R. A. Braden: American Ceramic Society, Toronto, Canada, April 1961

Space-Charge Current Measurement as a Technique for the Analysis of Trace Impurities in Ultra Pure Materials
R. W. Smith: Conference on Ultra-purification of Semiconductor Materials, Bedford, Mass., April 11-13, 1961

Thermoelectric Conversion
R. D. Rosi: North Jersey Section IRE, East Orange, N. J., April 12, 1961

Recent Work on the Bismuth-Silver Oxygen Cesium Photocathode
A. H. Sommer, MIT Electronics Conference, Cambridge, Mass., March 29, 1961

Injection and Extraction of Electrons in CdS Single Crystals
W. Ruppel: Semiconductor Meeting, German Physical Society, Bad Pyrmont, Germany, April 12-15, 1961

Some Aspects of Scientific Research
F. Herman: Faculty Enrichment Program, Pennington School, Pennington, N. J., April 19, 1961

Some Aspects of Crystal Chemistry of Spineis
A. Miller: Solid-State Chemistry Seminar at IBM, Watson Lab., Poughkeepsie, N. Y., April 19, 1961

The Optical Absorption Edge of Very Impure Germanium
J. I. Pankove: American Physical Society, Washington, D. C., April 24-27, 1961

Electromagnetic Radiation by Electrically Charged Bodies in Gravitational Fields
W. H. Cherry: American Physical Society, Washington, D. C., April 24-27, 1961

The Kapitza Boundary Resistance Between Normal and Superconducting Tin and Liquid Helium
J. I. Gittleman: American Physical Society, Washington, D. C., April 24-27, 1961

The Electron-Phonon Interaction in Metals
J. J. Quinn: American Physical Society, Washington, D. C., April 24-27, 1961

Frequency Dependence of Plasma Acceleration by RF Field Gradient
G. A. Swartz, T. T. Reboul, G. D. Gordon: American Physical Society, Washington, D. C., April 24-27, 1961

Effect of Illumination on the Paramagnetic Resonance of Ni^{3+} in Rutile
H. J. Gerritsen and E. Sabisky: American Physical Society, Washington, D. C., April 24-27, 1961

Electron-Hole Plasma Pinching in p-Type InSb
B. Ancker-Johnson, R. W. Cohen: American Physical Society, Washington, D. C., April 24-27, 1961

Lattice Absorption Bands and Clustering in Semiconductor Alloys
E. E. Loebner and E. W. Poor, Jr.: American Physical Society, Washington, D. C., April 24-27, 1961

Irreversible Changes in the Space Charge Region in Degenerate GaAs p-n Junctions
B. Goldstein, L. R. Weisberg and R. M. Williams: American Physical Society, Washington, D. C., April 24-27, 1961

Stabilization of Semiconductor Surfaces—I. Chemical Treatment, II. Electrical Measurement, and III. Chemical Analysis
G. W. Cullen, J. A. Amick and D. Gerlich: Semiconductor Symposium of Electrochemical Society, May 1-3, 1961

Syllable Analyzer, Coder and Synthesizer for the Transmission of Speech
H. F. Olson and H. Belar: NAECON Meeting, Dayton, Ohio, May 8, 1961

Tunnel Diode Transistor Digital Circuits
J. J. Amodei and W. F. Kosonocky: Western Joint Computer Conference, Los Angeles, Calif., May 9-11, 1961

Tunnel Diode Balanced Pair Circuits as Building Blocks for High-Speed Computers
H. S. Miller, W. E. Barnette, G. A. Brown, S. Fiarman and R. A. Powlus: Western Joint Computer Conference, Los Angeles, Calif., May 9-11, 1961

Aid to Music Composition Employing a Random-Probability System
H. F. Olson and H. Belar: Acoustical Society of America, Philadelphia, May 10-13, 1961

The Role of the Technical Specialist in Research
J. Kurshan: The MU Chapter of Epilson Phi Tau Fraternity, Princeton, N. J., May 19, 1961

Sysec: System Synthesizer and Evaluation Center
T. R. Sheridan: 5th Nat'l. Symp. on Global Communications, Chicago, Illinois, May 22-24, 1961

Glass and Metal Ultra High Vacuum Systems
R. E. Honig: American Scientific Glass Society Symposium, New York, May 24, 1961

Patents Granted TO RCA ENGINEERS

BASED ON SUMMARIES RECEIVED OVER A PERIOD OF ABOUT TWO MONTHS

RCA SERVICE COMPANY

Television Test Apparatus
2,975,229—March 14, 1961; S. Wlasuk

ELECTRON TUBE DIVISION

Semiconductor Devices Including Gallium-Containing Electrodes
2,977,262—March 28, 1961; C. L. Carlson and H. Nelson

Beam Deflection Type Electron Discharge Device
2,975,316—March 14, 1961; M. B. Knight

Methods for Preparing Water-Stable Zinc Orthophosphate Phosphors
2,977,321—March 28, 1961; H. E. McCreary

Art of Fabricating Electron Tubes
2,980,984—April 25, 1961; M. B. Shrader, M. R. Weingarten and F. G. Block

Art of Making and Testing Gettered Electron Tubes
2,979,371—April 11, 1961; R. L. Spalding

SEMICONDUCTOR AND MATERIALS DIVISION

Introduction of Barrier in Germanium Crystals
2,978,367—April 4, 1961; A. L. Kestenbaum and S. W. Daskam

Production of Controlled P-N Junctions
2,975,080—March 14, 1961; L. D. Armstrong

Method of Making Phosphorus Diffused Silicon Semiconductor Devices
2,974,073—March 7, 1961; L. D. Armstrong

Multivibrator Circuit
2,974,238—March 7, 1961; R. D. Lohman

INDUSTRIAL ELECTRONIC PRODUCTS

Tuning Section
2,976,500—March 21, 1961; J. J. Matta and L. A. Brockwell

Static Convergence Magnet for Tri-Color Kinescope
2,975,314—March 14, 1961; B. R. Clay and C. E. Small

Coupling Device for Slot Antenna
2,981,947—April 25, 1961; S. J. Bazan

Shading Voltage Circuitry
2,981,793—April 25, 1961; W. L. Hurford

Deflection Yoke Assembly for Cathode Ray Tubes
2,980,815—April 18, 1961; M. E. Ecker

Color Television Receiver Color Demodulation Apparatus
2,980,762—April 18, 1961; R. W. Sonnenfeldt

Transistor-Sync Separator and Automatic Gain Control Circuit
2,979,563—April 11, 1961; M. C. Kidd

Film Viewer and Reproducer
2,979,026—April 11, 1961; H. G. Reuter, Jr.

Time Discriminator
2,975,299—March 14, 1961; A. I. Mintzer

Portable Disk-Type Magnetic Recording Apparatus
2,975,238—March 14, 1961; L. F. Jones

Servomotor Damping Arrangement
2,977,517—March 28, 1961; S. Baybick

Electron Lens
2,976,457—March 21, 1961; J. H. Reisner

Clutch Control
2,973,846—March 7, 1961; A. Burstein

DEFENSE ELECTRONIC PRODUCTS

Radar Systems with Gain Equalization Circuits
2,977,588—March 28, 1961; N. I. Korman

Antenna Feed System
2,981,946—April 25, 1961; N. I. Korman

Static Convergence Magnet for Tri-Color Kinescope
2,975,314—March 14, 1961; C. E. Small and B. R. Clay

Tuning Section
2,976,500—March 21, 1961; L. A. Brockwell and J. J. Matta

Balance Indicator for Stereophonic Sound Systems
2,980,766—April 18, 1961; J. H. Nulton, Jr. and J. R. Shoaf II

Electrostatically-Shielded Loop Antenna
2,981,950—April 25, 1961; W. S. Skidmore

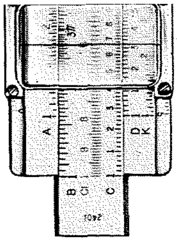
Series Energized Transistor Amplifier
2,981,895—April 25, 1961; W. R. Koch

Acoustical Impedance Meter
2,981,096—April 25, 1961; R. M. Carrell

Television Test Apparatus
2,978,540—April 4, 1961; R. S. Coate and S. Koren

Protective System Against Damaging Rays
2,976,758—March 28, 1961; D. J. Parker

Automatic Gain Control Circuits
2,977,411—March 28, 1961; H. C. Goodrich

Engineering  NEWS *and* HIGHLIGHTS

LABS PRESENT 1960 ACHIEVEMENT AWARDS

The RCA Laboratories have named the following as recipients of 14th annual *RCA Laboratories Achievement Awards.* These 1960 awards are in recognition of outstanding contributions by members of the RCA Laboratories.

G. R. Briggs, *for the conception and analysis of new magnetic devices.*

E. Fatuzzo, *for fundamental studies and ingenious applications of ferroelectrics.*

J. J. Gibson, *for analytical studies of FM stereophonic broadcast systems.*

B. Goldstein, *for definitive radiotracer studies of self-diffusion and impurity diffusion in crystals of III/V compounds.*

J. Gross, *for contributions to the analysis of magnetic fields and the practical interpretation of the analysis.*

E. F. Hockings, *for research yielding new semiconductors, particularly for thermoelectric power generators with superior efficiency.*

Mrs. Helene E. Kulsrud, *for the development of high-speed digital computer techniques useful in the design of electron guns.*

D. S. McCoy, *for basic studies of the subjective and objective aspects of auditory perspective.*

F. E. Paschke, *for major contributions to the nonlinear theory of electron beams.*

D. W. Peterson, *for the development of specifications and test procedures for television broadcast-antenna systems.*

R. A. Shahbender, *for research leading to improved high-speed computer-memory devices.*

R. Williams, *for the elucidation and exploitation of the boundary-layer phenomena of semiconductors.*

G. A. Alphonse, L. L. Burns, Jr., and **G. W. Leck, Jr.,** *for team performance in research on cryo-electric devices and technology.*

J. Berghammer and **S. Bloom,** *for team performance in theoretical studies of noise reduction in electron beams leading to decreased noise figures of traveling-wave tubes.*

K. K. N. Chang, G. H. Heilmeier and **H. J. Prager,** *for team performance in the conception and development of oscillator, amplifier, and converter circuits using tunnel diodes and parametric diodes.*

W. F. W. Dietz and **R. N. Rhodes,** *for team performance leading to the development of circuitry for improving the noise immunity of television receivers.*

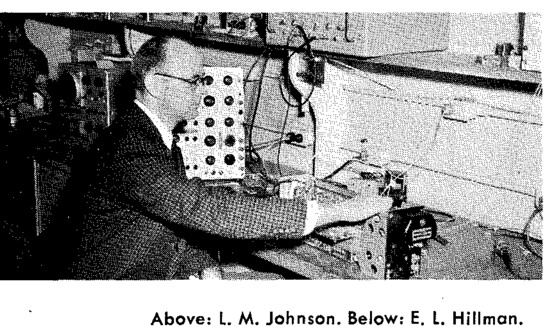
W. E. Harty and **M. L. Schultz,** *for team performance in research leading to new photoconductors and photoconductive cells sensitive to long-wave infrared radiation.*

R. E. Simon and **W. E. Spicer,** *for team performance in research on field-induced photoemission from semiconductors.*

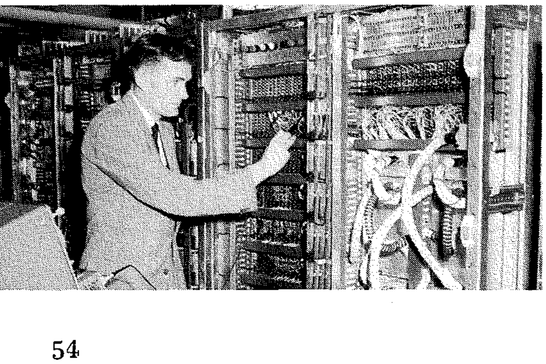
JOHNSON, HILLMAN NAMED "IEP ENGINEERS OF THE MONTH" FOR MAY, JUNE.

The series of *IEP Engineer-of-the-Month* Awards recently came to a close with the selection of **L. M. Johnson** as May IEP Engineer-of-the-Month, and **E. L. Hillman** as June IEP Engineer-of-the-Month. Both engineers received mementos of the awards at engineering dinners, separated by 3000 miles.

L. M. Johnson of the Custom Aviation Equipment Department, Los Angeles, California, was presented with a desk pen set on May 11, 1961, at an engineering dinner attended by IEP and DEP personnel. The guest speaker was **A. N. Curtiss,** General Manager of the DEP Plant at Van Nuys, California. **Mr. Shirley,** Manager of the Custom Aviation Equipment Department, presented the award to Mr. Johnson for his part in the redesign of a Transponder Beacon for the Civil Aeronautics Administration. He was instrumental in greatly shortening the design and test cycle through the manner in which he utilized his experience and professional ability on the project. The faculty of imparting his background knowledge to other members of the design team was particularly valuable.



Above: L. M. Johnson. Below: E. L. Hillman.



E. L. Hillman of the Data Communications and Custom Projects Department, EDP Division, received his desk pen set from **W. C. Morrison,** Manager, Engineering Plans and Services, at an engineering dinner held at the Ivystone Inn, Pennsauken, N. J., on June 7, 1961. March and April recipients of the Award were given their mementos at this dinner also. The guest speaker, **Dr. E. W. Engstrom,** spoke on "Understanding Our Scientific Age." Mr. Hillman's technical abilities were amply demonstrated by his major role in the conception and design of the Accumulation and Distribution Unit for the ComLogNet System. This unit will be a major achievement by RCA in the field of message-handling networks. The professional skill exhibited by Mr. Hillman contributed to his recent promotion to Leader in the Design Engineering section, of which **T. L. Genetta** is Manager.—*S. F. Dierk*

OSBORNE WINS SLOAN FELLOWSHIP

J. M. Osborne, who has been a DEP Project Manager in Camden, has been awarded a 1961-62 *Alfred P. Sloan Fellowship in Executive Development* at the Massachusetts Institute of Technology. Mr. Osborne was recently cited by the U. S. Navy for his leadership on the Navy's Project Boresight.

Prior to that, he had served as Project Manager on RCA's North Atlantic Tropospheric Scatter program, and participated in an RCA missile project.

Mr. Osborne holds a BSEE from the University of Texas, and completed courses there for an M.S. He also was graduated from the Industrial College of the Armed Forces.

NAVY COMMENDS DEP

In a letter to **A. L. Malcarney,** Executive Vice President, DEP, R. K. James, Rear Admiral, USN, Chief of the Bureau of Ships, commended RCA for its completion within a stringent 10-month schedule of equipment for BORESIGHT, a project "*. . . of utmost importance and urgency to the Navy and the nation.*" In his letter, Rear Admiral James stated:

"The performance of RCA on this Project has been outstanding . . . The myriad of technical and logistic problems met and solved has been little short of over-whelming. The successful completion of the Project has been a major contribution to the national security. The DEP Group cannot be praised too highly for its performance... I wish to thank you for the lively interest and assistance manifested by all echelons of RCA management . . . Without your personal attention, snags could easily have occurred to delay accomplishment. Please extend to members of the Project organization, headed by **Mr. James M. Osborne,** *my appreciation for their efforts."*

NEW WING STARTED AT LABS

For the ninth time in the 20-year history of the Princeton Laboratories, a major building program has been undertaken. A new wing will extend toward U. S. 1 from the northeast portion of the present research center.

Scheduled for occupancy in early 1962, it will provide 33,000 square feet of new space and will house forty new laboratories. Increasing research emphasis upon new and improved semi-conductors, insulators, and luminescent and magnetic materials has generated a growing need for special facilities such as large magnets, mass spectrographs, particle accelerators, and high-temperature furnaces.

The RCA Laboratories has approximately doubled in size since its establishment at Princeton in 1942. The research staff itself has increased 40 percent in the last four years alone.

SURF-COM CONTROLLED-ATMOSPHERE FACILITY NEARS COMPLETION

One of the world's largest and most flexible "controlled atmosphere" production facilities will be completed soon at the Cambridge, Ohio, plant of DEP-SurfCom.

The 40,000 square-foot *White Room* is designed for protection against temperature variation, dust-particle content, and other atmospheric conditions.

DEGREES GRANTED

DEP-MSR, Moorestown: **Dr. S. B. Adler,** Mgr., Radar and Information Handling, received his PhD in Physics from Temple University in June 1961. Also at Moorestown, **Dr. S. Shucker,** Systems Engineer, (RCA ENGINEER co-author this issue) received his PhD in EE from the University of Pennsylvania in June 1961.—*T. G. Greene*

DEP-AppRes, Camden: **Dr. L. Zelby** received his PhD in Physics from the University of Pennsylvania in February 1961. —*F. W. Whittier*

DEP-SurfCom, Camden: **J. O. Sheldahl** received his MSEE from the University of Pennsylvania in February 1961.—*C. W. Fields*

In DEP-ACC, Camden: **G. Hennessy** was granted his MSEE by the University of Pennsylvania in February 1961.—*J. L. Connors*

RCA REPORTS HIGHEST FIRST-QUARTER SALES

RCA recorded the highest first-quarter sales in its history, while earnings declined slightly from last year's peak, President **John L. Burns** announced at the 42nd Annual Meeting of RCA Shareholders on May 2, 1961.

Sales of products and services amounted to $361,700,000, compared with $361,200,000 in the first quarter of 1960. Net profit after taxes was $12,000,000, 8 percent less than the record $13,000,000 in the first three months of 1960. Earnings per common share were 68 cents, compared with 85 cents in the 1960 quarter when a substantially smaller number of shares were outstanding.

The lower earnings in the 1961 quarter reflect continuing heavy investment in electronic data processing. It is felt that RCA is now at the peak period of data-processing costs; they are expected to decline appreciably, beginning in 1962.

Six important areas of RCA business show important trends:

1) Color-TV receiver sales rose significantly above 1960's first quarter, and now contribute approximately one out of every three dollars of RCA's total TV receiver sales and an even larger share of receiver profits.

2) NBC's color programming increased 70 percent over the January-March period a year ago, supplemented by local color offerings from more than 100 stations.

3) Nine other companies will soon be driving for a major marketing breakthrough in color. The additional manufacturers should push the color-TV industry volume well beyond $100 million a year.

4) In a surprisingly short time, RCA has become a leading producer of electronic computers and associated equipment.

5) The build-up of data-processing operations proceeds swiftly. The Wall Street EDP Center is running at capacity. In San Francisco, RCA opened its fifth EDP Center.

6) In a first quarter that saw the earliest buying season in television history, NBC shared significantly in the mounting vote of dollar confidence by America's biggest advertisers. NBC is well on the way to surpassing its 1960 mark, when it led all networks in total number of advertisers with 247.

ENGINEERS IN NEW POSTS

In IEP, **N. R. Amberg** has been named Mgr., Detroit Industrial and Machine Tool Dept., succeeding **I. C. Maust. E. M. Hinsdale,** Chief Engineer, Comm. Products Dept., Comm. and Contr. Div., announces his staff as follows: **L. J. Anderson,** Mgr., Audio Products Engineering; **N. C. Colby,** Mgr., Systems Engineering; **K. L. Neumann,** Mgr., Two-way Radio Engineering; **W. D. Rhoads,** Mgr., Sustaining and Special Products Engineering; **G. F. Rogers,** Mgr., Advanced Development; and **J. E. Volkmann,** Staff Engineer. Also in that Division, **J. D. Seabert** has been named Coordinator, Mechanical Design under **N. M. Brooks,** Chief Engineer, Industrial Controls.

In the Home Instruments Div., **E. I. Anderson,** Chief Engineer, names his staff as follows: **K. A. Chittick,** Mgr., Engineering Administration and Services; **D. H. Cunningham,** Mgr., Mechanical and Electromechanical Product Engineering; **L. P. Kirkwood,** Mgr., TV Product Engineering; **L. M. Krugman,** Mgr., Radio-*Victrola* Product Engineering; and **W. Y. Pan,** Mgr., Advanced Development Engineering.

In DEP, **H. R. Wege,** Vice President had Gen'l. Mgr., Missile and Surface Radar, has named **J. B. Cecil** Administrator, Data Processing Plans.

In RCA International, **D. C. Lynch,** Vice President and Managing Director, has named **J. M. Toney** as Division Vice President, Italian Project, New York.

In the Electron Tube Division, **H. A. DeMooy,** Mgr., Receiving Tube Operations, names his staff to include: **W. B. Brown,** Plant Mgr., Woodbridge Plant; **J. T. Cimorelli,** Mgr., Engineering; **G. W. Farmer,** Plant Mgr., Indianapolis Tube Plant; **C. W. Hear,** Mgr., Operations Planning; **F. J. Lautenschlaeger,** Plant Mgr., Harrison Plant; **J. W. MacDougall,** Administrator, Controls and Standards; **E. Rudolph,** Mgr., Equipment Design and Development; and **N. A. Stevens,** Plant Mgr., Cincinnati Plant.

S. L. ARENSBERG DIES

S. L. Arensberg, a DEP Moorestown engineer well known for his work in consoles and displays, died of a heart attack on May 21, 1961. He studied architecture and engineering at Carnegie Institute from 1927-29, and worked with Westinghouse and Elliot Co. before coming to RCA in 1939. He had currently been with the Displays, Analog, and Switching Group, Radar Design and Development Engineering, Moorestown. He is survived by his wife and three children.

DREXEL HONORS ZAPPACOSTA

A. D. Zappacosta, Manager, Project Design, DEP-SurfCom., Camden, was honored with a scroll and a gift on May 20, 1961 by the Drexel Evening College Alumni Association, for outstanding performance in engineering. The Alumni Association presents these awards annually to engineers of five different graduating classes; Mr. Zappacosta was chosen out of the class of 1936. —*C. W. Fields*

W. B. O'CONNOR KILLED IN PLANT ACCIDENT

W. B. O'Connor, Design and Development, DEP Moorestown, was killed accidentally on June 2, 1961 at the RCA Electron Tube Div. Plant in Lancaster, Pa. He had been working on a project there for about a month. O'Connor was one of three engineers conducting a testing program on high-power electrical apparatus; the accident resulted from contact with high-power circuit equipment. It was the first accident of its kind in the history of the Lancaster plant.

Mr. O'Connor, who was 39 years old, received his BSEE from Drexel in 1955 and had been with RCA since 1953. He is survived by his wife, Eileen, and seven children.

RCA AUTHOR'S ARTICLE APPEARS IN RUSSIAN JOURNAL

A summary of "Effect of Operating Frequency on the Weight and Other Characteristics of Missile Alternators and Transformers" an article written by R. E. Turkington, of DEP-ACC, Burlington, and published in the *AIEE Application and Industry,* 1958, No. 29, 289-300, has been published in a Russian Journal. Scientific Information Consultants, London, referred The Russian article to the author.—*R. E. Glendon*

BEHIND THE SCENES—RCA INSTITUTES BOARD OF TECHNICAL ADVISORS

Four times each year, the Board of Technical Advisors to the RCA Institutes (see photo) meet in New York to guide the technical education requirements of the Institutes. Chairman of the Board is **Dr. A. N. Goldsmith,** Sr. Technical Consultant to RCA. Other members are from the management of various RCA Divisions in order to best represent all aspects of RCA work.

Members of the Board include: **C. Frost** and **D. S. Rau,** IEP-RCAC; **G. M. Nixon,** NBC; **Dr. G. R. Shaw** and **E. C. Hughes,** Tube Div.; **L. A. Shotliffe,** RCA International; **E. Stanko** and **M. G. Gander,** RCA Svc. Co.; **W. C. Morrison** and **I. F. Byrnes,** IEP; and **J. S. Donal, Jr.,** RCA Laboratories.

Nonmembers from the RCA Institutes who prepare material for the Board's review include: **Gen. G. L. Van Deusen, B. Hubbel, W. Horizny, J. Brody, P. Stein, H. Fezer,** and **J. Friedman.** Instruction material is reviewed, approved, and sent to the N.Y. State Board of Regents for approval. Latest teaching methods using recorders, TV, and computers are evaluated and recommendations for applications made.

RCA Institutes Board of Technical Advisors Meeting, RCA Board Room, Radio City, N.Y.

REGISTERED PROFESSIONAL ENGINEERS

D. G. Rosenzweig, DEP .... Prof. Eng. 7433E, Pa.

G. Wells, DEP .... Prof. Eng. 11586, N. J.

PROFESSIONAL ACTIVITIES

DEP-SurfCom, Camden: **T. H. Story** was elected Vice-Chairman of the Philadelphia Section, AIEE, for 1961-62; he had been Secretary during 1960-61. **D. R. Marsh** was named Chairman, Communications technical Division. **P. Riley** was Convention Chairman for the 5th Annual IRE PGPEP Conference, Philadelphia, June 14-15; **J. Knoll** was Program Chairman. **A. M. Burke** is Chairman of the IRE-PGEWS Conference on Technical-Scientific Communications. Philadelphia, Sept. 13-14, 1961.

DEP-AppRes, Camden: **Dr. H. J. Woll,** Mgr., Applied Research, has been elected Vice Chairman of the Philadelphia Section, IRE, for 1961-62. **T. B. Martin** spoke to the student branch of the IRE at the University of Delaware on April 6, 1961 on "Future Computers."*—F. W. Whittier*

DEP-AED, Princeton: **Dr. J. Minker** has been invited to lecture on "Information Processing" at the Gordon Research Conference on Scientific Information Problems in Research during the week of July 4, 1961 in New Hampton, N. H. *(—R. E. Mueller).* **S. Metzger** is Chairman of the Communications and Instrumentation Session of the National IAS-ARS Joint Meeting, Los Angeles, Calif., June 13-16, 1961.

DEP-ACC, Camden: **B. Glazer** and **E. Nossen** are teaching an in-plant course in "Digital Logic." **A. L. Lane** reviewed C. Glickstein's book, *Basic Ultrasonics,* in the Dec. 1960 *Proceedings of the IRE.* *(—J. L. Connors).* **O. T. Carver** is a member of the Program Committee of the Philadelphia Chapter, IRE-PGMIL, for 1961; he will be Vice Chairman next year. *(—D. Dobson)* **A. B. Sally** is Publicity Chairman for the IRE-PGEWS Conference on Technical-Scientific Communications, Philadelphia, Sept. 13-14, 1961.

SCM, Mountaintop: **H. W. Menzel** has been appointed to the Electronic Advisory Committee for the Wyoming Valley Technical Institute, Kingston, Pa.*—N. N. Slater*

IEP-Broadcast, Camden: **J. Goldsmith** has been elected Secretary-Treasurer of the Associate Section, Philadelphia Branch, ASME.*—C. D. Kentner*

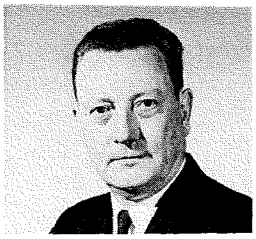
DEP-Staff, Camden: **F. L. Ankenbrandt** is Convention President for MIL-E-CON 1961, June 26-28, 1961, Washington, D.C.

DEP-CE, Camden: **H. Olsen** is handling publicity for the 5th Annual PGPEP Conference. Philadelphia, June 14-15, 1961.

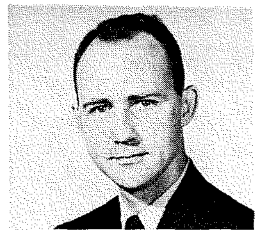
DEP-MSR, Moorestown: **W. Welsh** was in charge of registration for the 5th Annual PGPEP Conference, Philadelphia, June 14-15, 1961. **H. W. Phillips** has been named Vice President of the NSPE Engineering Society of Southern New Jersey. **F. Klawsnik** was recently named Chairman of the IRE Joint Professional Groups on Antenna and Propagation, and Microwave Theory and Techniques. During National Engineer's Week, Feb. 20-26, 1961, several talks were given to civic groups, presented under the sponsorship of the NSPE Engineering Society of Southern N. J. Men active in this effort, coordinated by **H. W. Phillips** and **J. F. Walsh,** included: **J. R. Levitt, R. C. Shafer, J. J. O'Donnel, J. M. Bailey, Jr., J. W. Bornholdt,** and **E. R. Brown.** For the 3rd Annual Science Fair of the Rancocas Valley Regional H.S., Mt. Holly, April 5, 1961, the following engineers served as judges: **J. Gorman, R. S. Putman,** and **J. Levitt;** over 580 exhibits were involved *(T. G. Greene).* **W. Welsh** is handling registration for the 5th Annual IRE-PGPEP Conference, Philadelphia, June 14-15, 1961.

IEP-RCAC; New York: **W. Lyons** was Moderator for the H-F Communications Session Globecom V, Chicago, May 22-24.

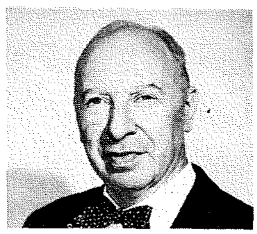
RCA Staff, Camden: **E. R. Jennings** is Program Co-Chairman for the IRE-PGEWS Conference on Technical-Scientific Communications, Philadelphia, Sept. 13-14, 1961.



J. B. Rippere



E. E. Anschuetz



J. D. Seabert

M. N. Slater

NEW ED REPS IN DEP, IEP, HOME INSTRUMENTS, TUBE, AND SC&M

In the DEP Aerospace Comm. and Contr. Div., **J. B. Rippere** (see biog., below) has been named an Ed. Rep., replacing **J. Biewener; E. E. Anschuetz** (see biog., below) has been named Ed. Rep. in that Division for Communications Engineering; **R. W. Howery** is appointed Ed. Rep. for the Moorestown M & S R Div., replacing **I. N. Brown,** who will act as Editorial Representative for the new DEP Major Defense Systems Division, Moorestown. In ACC, Burlington, Mass., **R. Glendon** has replaced **R. W. Jevon** as Ed. Rep. All will be active on **F. D. Whitmore's** DEP Editorial Board.

In IEP, changes to **S. F. Dierk's** Editorial Board include: **J. D. Seabert** as new Ed. Rep. for Industrial Controls, Comm. & Contr. Div., Camden, replacing **J. J. Hoehn.** Mr. Seabert will also represent the area formerly covered by **J. E. Volkmann.**

A new Ed. Rep. organization has been named for the Home Instruments Div., in line with their move to Indianapolis. **K. A. Chittick's** Editorial Board will now include: **D. J. Carlson,** Adv. Devel. Eng., located at the RCA Laboratories, Princeton; **R. C. Graham,** Radio-*Victrola* Product Eng., Indianapolis; **J. Osman,** Electromechanical Product Eng., Indianapolis; **L. R. Wolter,** and **P. G. McCabe,** TV Product Eng., Indianapolis; and **E. J. Evans,** Resident Eng., Bloomington, Ind.

On **J. H. Hirlinger's** Electron Tube and SC&M Divisions' Editorial Board, **M. N. Slater** has been named as Ed. Rep. for both Division's activities at Mountaintop, Pa. For the SC&M Needham Materials Operation, **G. R. Kornfeld** has replaced **G. I. Small** as their Ed. Rep.

The *Editors* extend warm thanks to all those leaving Ed. Rep. posts, and welcome those assuming the new duties. Following are the backgrounds of Messrs. **Rippere, Anscheutz, Seabert,** and **Slater.** Information on others will follow in future issues.

J. B. Rippere (Col., USAF, ret.), Staff Engineer, Aerospace Comm. and Contr. Div., Camden, joined RCA in August 1960 immediately after his retirement from the USAF with 24 years of service. Under **J. D. Woodward,** Chief Engineer, ACC, Camden, he is responsible for applied-research and development programs. He holds a BS in Aeronautical Eng. from the University of Alabama. During his military career, he received the MS in Civil Eng., from MIT in 1939, completed the Electronics Course in 1948-50 at the USAF Inst. of Tech., and was graduated from the Air War College in 1956. In the USAF, he was responsible for R&D programs in communications and navigation.

E. E. Anscheutz received the BS in Eng. Admin. from MIT in 1950. Prior to coming to RCA in 1960, he was with the Sperry Gyroscope Co. for 7 years, working on the B-58 program, as a Program Planner and Technical Coordinator. Prior to Sperry, he has been a guided missile instructor in the Army, and a liaison engineer with the Standard Register Co. He is now a Leader in the Communications Eng. Section, under the Mgr., Aerospace Communications Eng.

J. D. Seabert received his BSEE from Carnegie Institute of Technology in 1924. He then joined Westinghouse, and later General Motors. In the past 25 years with RCA, he has been engaged in product design of electronic and electromechanical equipment ranging from loudspeakers for theaters, PA systems, and hi-fi through the beverage inspection machine. Prior to his recent assignment as Coordinator Mechanical Design, under **N. M. Brooks,** Chief Engineer, Industrial Controls, he was doing design work on the Electron Microscope.

M. N. Slater received the B.Sc. from the University of Manitoba in 1945, and has done graduate work at a number of Universities. He joined the Tube Division in 1951 in the Chemical and Physical Laboratory at Marion, transferring to Lancaster in 1956. His work includes kinescope glass-metal seals, filming, aluminizing, coatings, adhesives, and radiotracers. He switched to the SC&M Division at Lancaster in the Silicon Rectifier Design Activity, and recently moved to that Division's Mountaintop, Pa. Plant. He has authored articles in the RCA ENGINEER, and has previously served as an Ed. Rep.

Clip out and Mail to Editor, RCA ENGINEER, #2-8, Camden

RCA ENGINEER

HAVE WE YOUR CORRECT ADDRESS?

If not indicate the change below.

PLEASE INDICATE THE CODE LETTER(S) THAT APPEAR NEXT TO YOUR NAME ON THE ENVELOPE.

Name ______________________ Code ________

Street or Bldg. ______________________

City and State or Plant ______________________

Editorial Representatives

The Editorial Representative in your group is the one you should contact in scheduling technical papers and announcements of your professional activities.

DEFENSE ELECTRONIC PRODUCTS

F. D. WHITMORE *Chairman, Editorial Board*

Editorial Representatives

J. B. RIPPERE *Aerospace Comm. & Contr. Div., Camden, N. J.*

R. D. CRAWFORD *Design-Devel. Eng., Aerospace Comm. & Contr. Div., Camden, N. J.*

D. B. DOBSON *Systems Support Eng., Aerospace Comm. & Contr. Div., Camden, N. J.*

J. L. CONNORS *Systems Eng., Aerospace Comm. & Contr. Div., Camden, N. J.*

E. ANSCHUETZ *Comm. Eng., Aerospace Comm. & Control Div., Camden, N. J.*

R. GLENDON *Aerospace Comm. & Contr. Div., Burlington, Mass.*

I. N. BROWN *Major Defense Systems Div., Moorestown, N. J.*

R. W. HOWERY *Missile & Surf. Radar Div., Moorestown, N. J.*

D. J. ODA *West Coast Missile & Surf. Radar Div., Van Nuys, Calif.*

R. E. PATTERSON *Surf. Comm. Div., Camden, N. J.*

L. A. THOMAS *Astro-Elec. Div., Princeton, N. J.*

F. W. WHITTIER *Applied Research, Def. Eng., Camden, N. J.*

R. P. DUNPHY *Central Eng., Def. Eng., Camden, N. J.*

INDUSTRIAL ELECTRONIC PRODUCTS

S. F. DIERK *Chairman, Editorial Board*

Editorial Representatives

C. E. HITTLE *Closed Circuit TV & Film Recording Dept., Brdcst. & TV Equipment Div., Hollywood, Calif.*

C. D. KENTNER *Brdcst. Transmitter & Antenna Eng., Brdcst. & TV Equipment Div., Camden, N. J.*

J. H. ROE *Brdcst. Studio Eng., Brdcst. & TV Equipment Div., Camden, N. J.*

N. C. COLBY *Comm. Products Dept., Comm. & Controls Div., Meadow Lands, Pa.*

J. D. SEABERT *Industrial Controls, Comm. & Controls Div., Camden, N. J.*

R. R. HEMP *Commercial Systems Dept., EDP Div., Camden, N. J.*

M. C. KIDD *Industrial Computer Systems Dept., EDP Div., Natick, Mass.*

T. T. PATTERSON *Data Comm. & Custom Projects Dept., EDP Div., Pennsauken, N. J.*

J. H. SWEER *Advanced Systems Devel., EDP Div., Pennsauken, N. J.*

W. C. JACKSON *RCA Communications, Inc., New York, N. Y.*

ELECTRON TUBE DIVISION and SEMICONDUCTOR & MATERIALS DIVISION

J. F. HIRLINGER *Chairman, Joint Editorial Board*

Editorial Representatives, Electron Tube Div.

W. G. FAHNESTOCK *Conversion Tube Oper., Lancaster, Pa.*

J. H. LIPSCOMBE *B. & W. Kinescopes, Marion, Ind.*

J. D. ASHWORTH *Entertainment Tube Products, Lancaster, Pa.*

R. J. MASON *Receiving Tubes, Cincinnati, Ohio*

T. M. CUNNINGHAM *Entertainment Tube Products, Harrison, N. J.*

J. KOFF *Receiving Tubes, Woodbridge, N. J.*

H. S. LOVATT *Power Tube Oper. & Oper. Svcs., Lancaster, Pa.*

F. H. RICKS *Receiving Tubes, Indianapolis, Ind.*

H. J. WOLKSTEIN *Industrial Tube Products, Harrison, N. J.*

M. N. SLATER *Electron Tubes, Mountaintop, Pa.*

Editorial Representatives, Semiconductor & Materials Div.

G. R. KORNFELD *Needham Matls. Oper., Needham, Mass.*

R. SAMUEL *Microelectronics, Somerville, N. J.*

H. TIPTON *Semiconductor Devices, Somerville, N. J.*

J. D. YOUNG *Semiconductor Devices, Findlay, Ohio*

M. N. SLATER *Semiconductor Devices, Mountaintop, Pa.*

RCA VICTOR HOME INSTRUMENTS

K. A. CHITTICK *Chairman, Editorial Board*

Editorial Representatives

D. J. CARLSON *Advanced Devel., Princeton, N. J.*

R. C. GRAHAM *Radio "Victrola" Product Eng., Indianapolis, Ind.*

J. OSMAN *Electromech. Product Eng., Indianapolis, Ind.*

L. R. WOLTER *TV Product Eng., Indianapolis, Ind.*

P. G. McCABE *TV Product Eng., Indianapolis, Ind.*

E. J. EVANS *Resident Eng., Bloomington, Ind.*

RCA SERVICE COMPANY

W. W. COOK *Consumer Products Svc. Dept., Cherry Hill, N. J.*

M. W. TILDEN *Govt. Svc. Dept., Cherry Hill, N. J.*

E. STANKO *Tech. Products Svc. Dept., Cherry Hill, N. J.*

J. J. LAWLER *EDP Svc. Dept., Cherry Hill, N. J.*

RCA LABORATORIES

E. T. DICKEY *Research, Princeton, N. J.*

RCA VICTOR RECORD DIVISION

M. L. WHITEHURST *Record Eng., Indianapolis, Ind.*

NATIONAL BROADCASTING COMPANY, INC.

W. A. HOWARD *Staff Eng., New York, N. Y.*

RCA INTERNATIONAL

C. G. MAYER *Product Planning & Devel., Clark, N. J.*

RCA VICTOR COMPANY, LTD.

H. J. RUSSELL *Research & Eng., Montreal, Canada*