ELECTRONIC INDUSTRIES

TELE-TECH

A Caldwell-Clements Publication

NOVEMBER, 1953

FRONT COVER: RADAR MISSILE TRACKER is one of the many military devices operating in the microwave range. Developed by Electronic Engineering Co., Los Angeles, Calif., as a target location aid for the Naval Air Missile Test Center, this antenna tracks the signal from an FM/FM telemeter transmitter. It will orient the antenna axis within ±2° on targets whose elevation angle is above 10° to 20°. The system will lock on target over an angle of about ±60°.

DEPARTMENTS

TELE-TECH*, Vol. 12, No. 11. Published monthly by Caldwell-Clements, Inc. M. Clements, President; Orestes H. Caldwell, Treasurer. Acceptance under Section 34.64 Postal Laws and Regulations authorized at Bristol, Conn., February 8, 1952 with additional entry at New York, N. Y. 75c a copy. Annual Subscription Rates: United States and Possessions: $7.00; Canada: $8.00; All Other Countries: $10.00. Please give title, position and company connection when subscribing. Copyright by Caldwell-Clements, Inc., 1953. Printed in U.S.A.

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Publishers also of MART and TECHNICIAN

* Reg. U. S. Pat. Off.

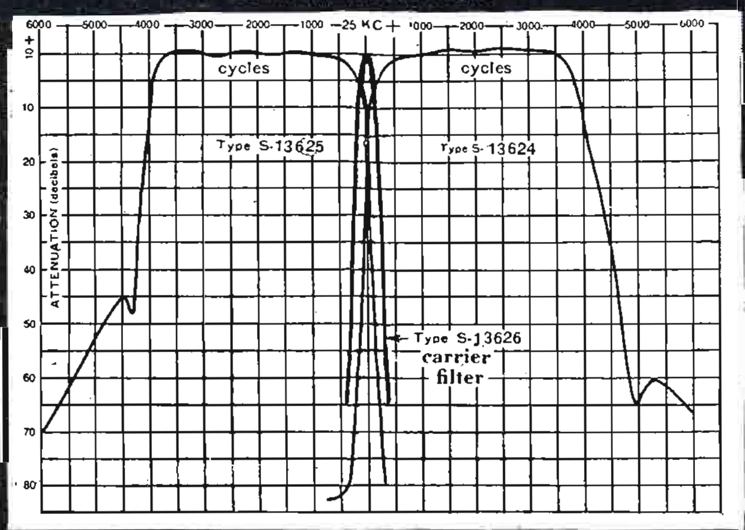
TELE-TECH'S CIRCULATION, 21,000

Because of increases in circulation which obviously cannot be shown in current audited statements, advertisers should disregard any comparison based on a previous period or any that fails to show TELE-TECH'S guaranteed circulation of 21,000.

RIGHT ON TOP

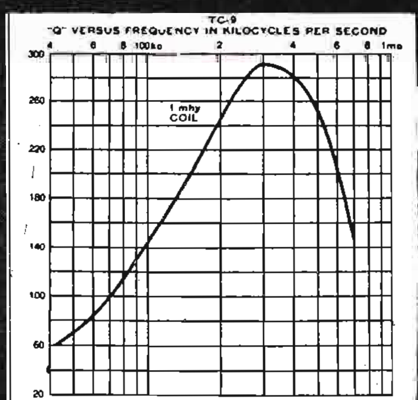
Burnell records a few of it's most recent engineering achievements in Toroids and Filter Networks.

SIDE BAND FILTERS



Our most recent engineering achievement in communications filters has already stirred the interest of the leading receiver manufacturers in the country.

Our new side band filters which eliminate, for most applications, the necessity for expensive crystal filters are expected to accelerate the advancement of single side band communications.



SUB MINIATURE TOROIDS

Toroids for intermediate frequencies of 100KC to 1 megacycle. A wide variety of coils ranging in size from 1/2 inch provides high Q in the frequency range between audio and RF.

The tiny toroid about the size of a dime has been welcomed by designers of sub miniature electronic equipment for the transistor, guided missile and printed circuit field.

PLUG IN DECADES

An entirely new development in inductance decades eliminating disadvantages of switch boxes. Inductance units plugged together in various combinations providing decade steps of inductance with minimum number of units required.

MINIATURE TELEMETERING FILTERS

In recognizing the need for miniaturization of the presently bulky telemetering equipment, our engineering staff has succeeded in reducing the size of telemetering filters to as little as 25 to 50% of the original volume.

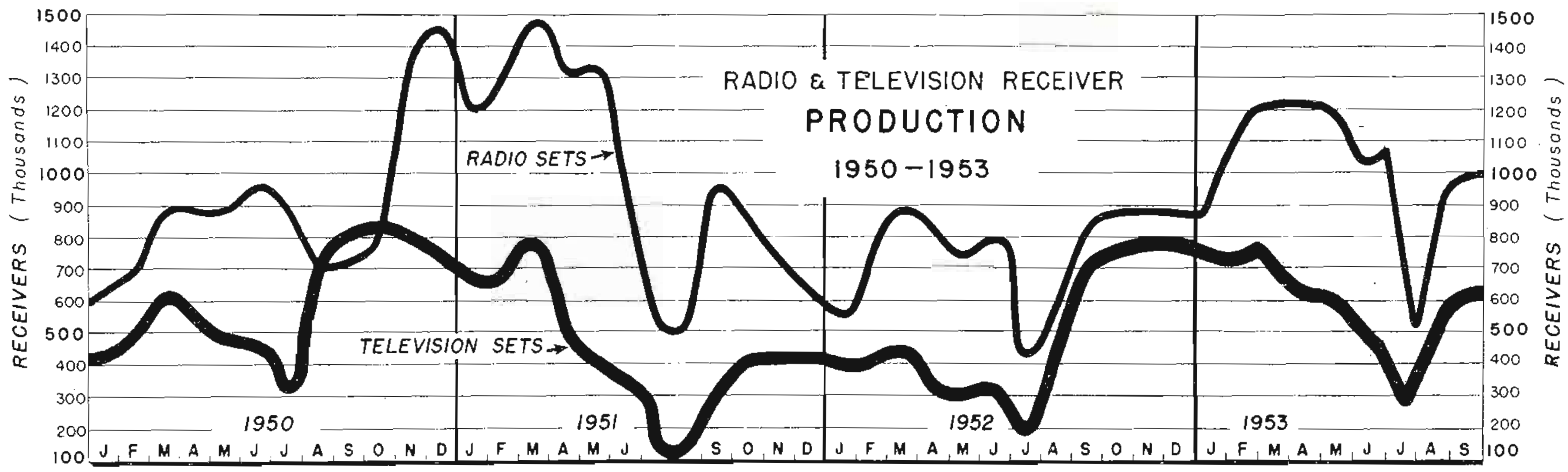
BURNELL & COMPANY is very pleased to announce that it now has available a 12 page catalog which includes valuable and complete information on toroids, high quality coils, and various audio filter networks.

The catalog includes complete descriptions, attenuation and Q curves that will prove valuable for equipment design engineers.

Write for Catalog 101-A.

Burnell & Company
YONKERS 2, NEW YORK
CABLE ADDRESS "BURNELL"

Exclusive Manufacturers of Communications Network Components



Broadcast Stations in U.S.

	AM	FM	TV
Stations on Air	2395	556	186 VHF 82 UHF
Under Construction (CPs)	131	66	96 VHF 175 UHF
Applications Pending	230	9	340 VHF 135 UHF

Radio & TV Receiver Production

	TV	Radio	
September, 1953		Home	407,000
		Battery	133,000
		Auto	302,000
		Clock	145,000
Total	620,000		987,000
Nine months, 1953 Jan.-Sept. Inclusive		Home	2,239,000
		Battery	1,425,000
		Auto	4,250,000
		Clock	1,600,000
Total	5,400,000		10,213,000

TV Sets in use, 26,700,000

With TV set sales to the public running about half a million per month, the number of receivers in use as of November 1 is estimated at 26,700,000.

By the end of the year, the figure is expected to add another 1,300,000, so that by January 1, 1954, television sets in use in the U.S. will total 28,000,000.

Electronic Outlook Bright into First Half of 1954

The electronic industries will continue to prosper briskly during the next nine months or longer, predicted Dr. Howard T. Hovde, addressing the National Electronic Distributors Association at St. Louis in September. Dr. Hovde is vice-president of the Econometric Institute, 230 Park Ave., New York.

Pointing out some of the important forces that will dictate the general outlook for the U. S. economy during the next nine months and during the next five years Dr. Hovde emphasizes the bright prospects for the electronic industry, and explained how his conclusions were reached.

"The Econometric Institute over the past fifteen years has been able to measure current economic pressures and to translate them into future economic changes. The methods used can be outlined very briefly.

Econometric Analysis

"Econometric analysis is based on nothing mysterious or obscure. It is a combination of the latest techniques in mathematics, statistics, and economics, tempered by a broad knowledge and able interpretation for current economic and political developments. The Institute, on the basis of these techniques, has been able to forecast production, income, prices, and in general, the pattern of the economy.

"The starting point of the Institute's analysis is new orders received by manufacturers. Experience has indicated that current orders correlate very closely with future national income, which is in effect a gauge of business activity. Thus, a knowledge of current new orders makes it possible to measure national income, purchasing power, and the demand for consumers' goods in the months ahead. The demand for consumers' goods and the relation of new orders to this demand determine how much producing capacity will be required.

"Econometric analysis is built up in this fashion. One step leads into another. Finally, every significant phase of the economy is forecast, including total income, real income, production broken down by types such as manufactured goods, raw materials, and retail prices.

Short-Term Business Outlook

"The economic climate in which you and your customers will do business during the next two or three quarters will be essentially favorable. Personal income will continue high through the first three months of 1954. This will serve to offset some of the less favorable factors that will influence the demand for radios and television sets through the first half of next year. Demand from business and from the military for electronic equipment will continue strong, though not at the current high rates."

GOVERNMENT ELECTRONIC CONTRACT AWARDS

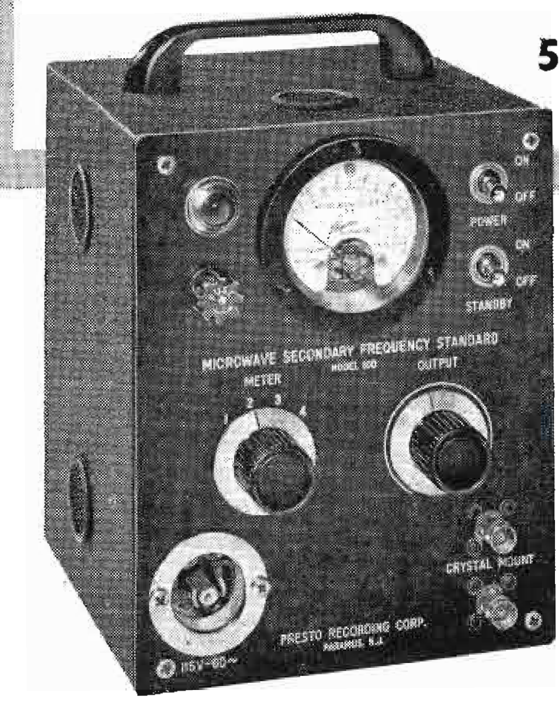
This list classifies and gives the value of electronic equipment selected from contracts awarded by government procurement agencies in Sept. 1953.

Actuators	$589,226
Batteries	40,945
Cable, transducer	25,200
Cable, submarine	434,313
Cathodes, nickel	26,641
Cavities, tuned	30,030
Chargers, Battery	339,333
Connector Plugs	39,810
Dummy Loads	37,288
Generators	825,451
Gyro Motors	67,211
Headsets	48,455
Indicators	344,193
Jack Box Assys	40,392
Junction Boxes	62,400
Microphones	57,497
Mountings, circuit	79,432
Oscilloscopes	50,500
Radar, GCA	215,877
Radio attachments	632,414
Rotors, motor generator	37,008
Simulators	392,425
Solder	78,730
Summation bridges	177,406
Switch Boxes, relay	62,745
Trainers, signal	51,004
Tubes, electron	268,175
Wattmeters	65,051

NOW!

UHF AND MICROWAVE MEASUREMENTS MADE EASY WITH THE PRESTO MICROWAVE SECONDARY FREQUENCY STANDARD

50-11,000 MC OUTPUT



MODEL 100*
Price: $265.00 f.o.b. factory

The PRESTO Model 100 Microwave Secondary Frequency Standard provides, for the first time, a versatile and relatively inexpensive instrument to generate accurate test signals over the extremely wide range of 50 to approximately 11,000 mc without any frequency tuning whatsoever. The Model 100 delivers to the 50 ohm input of a typical microwave receiver an uninterrupted, simultaneous series of CW signals spaced every 100 and 200 mc over its complete frequency range, and a 50 mc marker output useful up to approximately 9,000 mc.

- No frequency tuning whatsoever.
- Markers every 50, 100, 200 mc.
- .005% accuracy over range.
- Lightweight and compact—8½ lbs., 7⅜" x 6" x 6¼".
- Military quality standard components used throughout.
- Low power consumption—60 watts.
- Operates from 115V—50-1750 cycle source.

USE IT

- To perform functions of expensive primary standards.
- To calibrate signal generators.
- To establish standard frequencies.
- To calibrate and align receivers.
- To radiate test signals for overall radar systems check.
- To provide markers for panoramic displays.

*Patent Applied For

PRESTO RECORDING CORPORATION
PARAMUS, NEW JERSEY
SPECIALTY PRODUCTS DIVISION

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TELE-TECH* & ELECTRONIC INDUSTRIES is edited for top-level engineers and executives throughout the electronic industries. It gives the busy engineering executive authoritative information and interpretation of the latest developments and new products, with emphasis on subjects of engineering import and timeliness. Special attention is given to:

MANUFACTURING

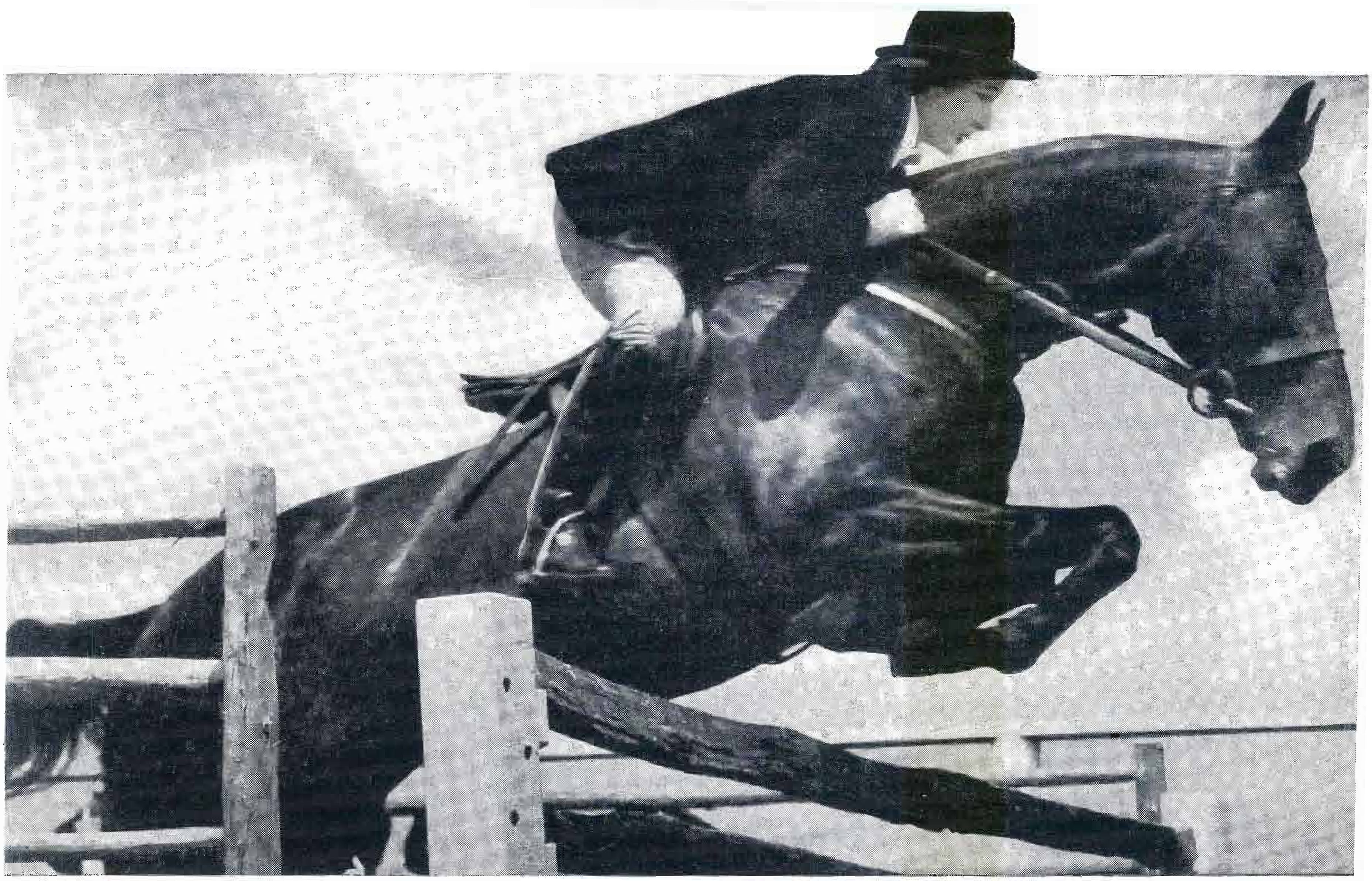
—Electronic equipment, communications, broadcasting, microwave relay, instrumentation, telemetering, computing.
—Military equipment including radar, sonar, guided missiles, fire controls.
—TV-FM-AM receivers, phonographs, recorders, reproducers.

OPERATION

—Fixed, mobile and airborne communications in commercial, municipal, aviation and government services.
—Broadcasting, video and audio recording, records, audio and sound systems, motion picture production.
—Military, civilian and scientific electronic computing and control systems.
*Reg. U. S. Pat. Off.

THE ELECTRONIC INDUSTRIES DIRECTORY

Published annually as an integral section of TELE-TECH in June



jumps are for Horses

... **NOT** *for magnetic tape*

That's why you need SOUNDCRAFT Micro-Polished Tape.*
No Raised Spots! No Roughness! No Jumps!
It's Smooth right from the start!

Under the microscope, magnetic tape may look like a steeplechase—replete with all the "jumps." As you record, these jumps—minute raised spots characteristic of all coating processes—momentarily separate large enough areas of the tape from the recording head to appreciably interrupt high-frequency response. On some equipment, they may even cause signal dropouts.

The Answer Is Micro-Polish

But Reeves SOUNDCRAFT eliminates the "jumps" with its exclusive Micro-Polish process, assuring the most complete head contact possible right from the start. That's because Micro-Polish smooths off the microscopic nodules by subjecting the ferrous oxide coating to high-precision polishing. It leaves the surface mirror-smooth, and preconditioned for immediate, stable, high-frequency response.

Breaking in tape by running it through the recorder, with accompanying head wear and waste of time, is a thing of the past.

Other SOUNDCRAFT Advantages

In addition, SOUNDCRAFT Recording Tapes are pre-coated with a special formulation to give utmost oxide adhesion, and prevent curling and cupping.

All tape is dry-lubricated to eliminate squeals and carries a splice-free guarantee on all 1200- and 2500-foot reels.

REEVES
SOUNDCRAFT
CORP.

10 East 52nd Street, Dept. N
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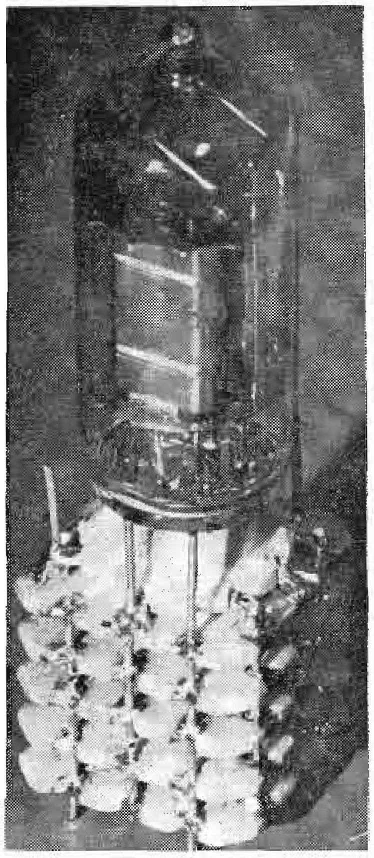
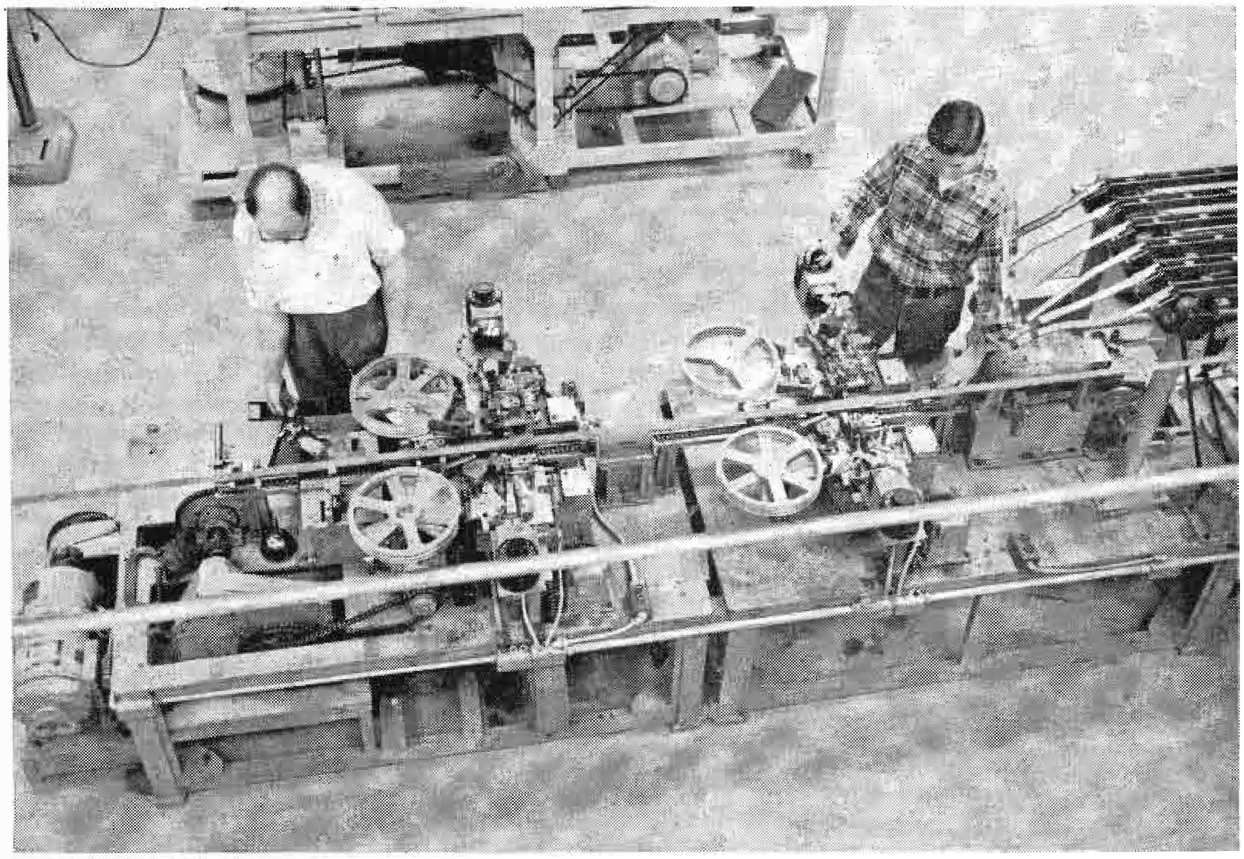
*Pat. Applied For.

As We Go To Press...

"Project Tinkertoy"—Automatic Production of Electronic Components





Tinkertoy module (l) comprises stack of steatite wafers upon which are mounted silver conductors, tape resistors and capacitors, as well as tube. In module assembler (r) parts-mounted wafers are loaded in feeders that issue single, oriented wafers into stacking jig. Simultaneous soldering operations bond riser wires to the wafer notches. This is one of a series of automatic production machines described on page 70

Project Tinkertoy is the code name of a program to develop a mechanized production system for electronic components to meet emergency military needs. The project was sponsored by the Navy Bureau of Aeronautics in June 1950, and carried out by the National Bureau of Standards, in cooperation with several companies. The result of this industrial preparedness program is an operating plant turning out printed capacitors and resistors on ceramic wafers. The wafers are stacked to make up a neat module. The modules are combined to make up a subassembly. These parts undergo 100% inspection.

Exactly how this new departure in automatic production is accomplished, and what the $4,700,000 Project Tinkertoy means to the electronic industries, is explained on page 70.

NTSC Color TV Showing a Resounding Success

Full-dress technical display of compatible standards shown to FCC

A demonstration utilizing compatible color TV standards proposed by the National Television System Committee was conducted in New York's Waldorf-Astoria Hotel on Oct. 15. It was witnessed by members of the FCC and the TV industry try. The quality of the color pictures was excellent, and all receivers performed without a single failure.

Thirteen manufacturers supplied color receivers to display the pictures transmitted during four tests. They are: CBS-Columbia, Hazeltine, Admiral, Zenith, Hallicrafters, Westinghouse, Sylvania, Crosley, RCA, General Electric, Motorola, Philco and Emerson.

Three broadcasting companies cooperated in showing the culmination of over a million engineering man-hours. In the first test, a live pick-up from the Colonial Theater was transmitted by Telephone Co. circuit to NBC studios, and then broadcast by WNBT, channel 4, atop the Empire State Building.

The second test was a closed circuit transmission employing both coaxial cable and microwave relay from NBC in New York to Washington, D.C., and back again. The routes were 540 mi. for radio, and 500 mi. for coax.

The third test was a live outdoor pick-up by CBS using a 7000 MC link to WCBS-TV, channel 2, at Empire State, which broadcasted the program.

The fourth test consisted of NTSC test slides transmitted by DuMont in New York in the UHF band, 708-714 MC.

For schematic diagrams of the tests and demonstration facilities see page 148.

MORE NEWS on page 15

Compact Navigational Radar Developed

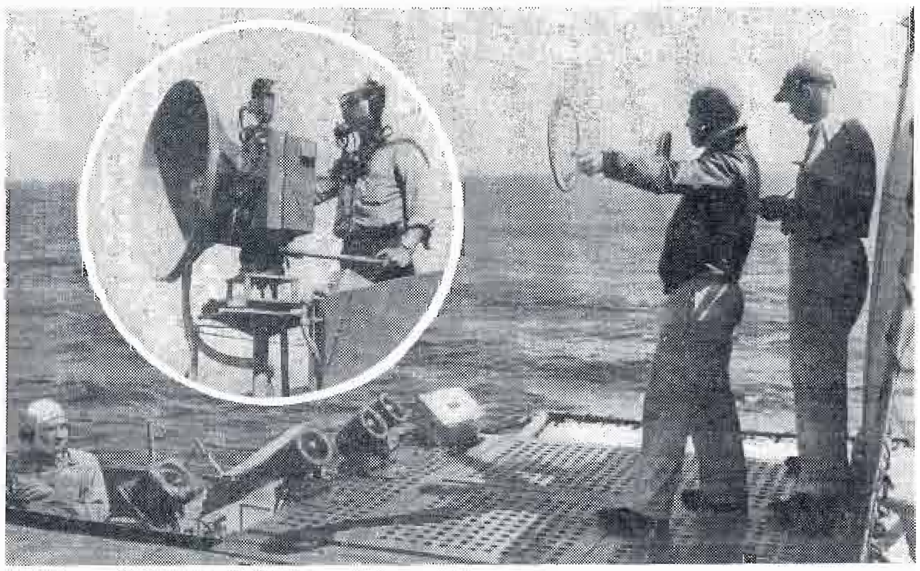
Raytheon Mfg. Co. has developed a navigational radar system particularly suited for small and medium commercial ships and pleasure craft. It features small size, moderate cost and retains all "big ship" type features. Designated the "Mariners Pathfinder" Model 1500, the radar is made up of just two units requiring only three interconnecting cables.

New radar helps skipper of ocean-going tug thread his way through crowded harbor in fog

The elimination of waveguide is made possible by including the transmitter in the antenna assembly. The low loss from this source, coupled with that of a balanced crystal mixer, enables the use of a low-power transmitter (7 kw peak power) while getting detection ranges equivalent to much higher powered transmitters. The Model 1500 is capable of detecting targets at ranges of 50 yards or less.

System elements which are located in the antenna include the magnetron, local oscillator, T-R tube, balanced crystal mixer and cascade preamplifier. The remainder of the receiver and of the system power supplies are located in the indicator.

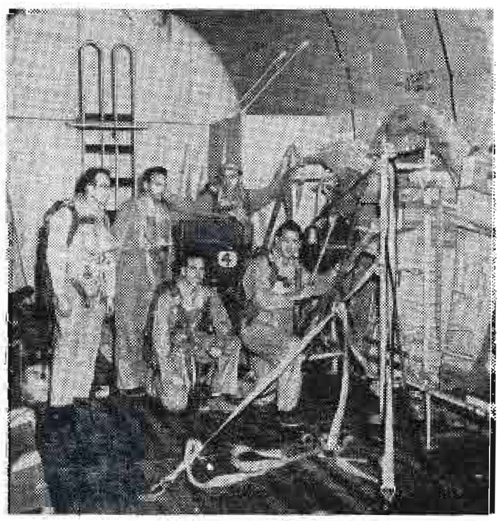
SPEED-MEASURING RADAR CLOCKS PLANES



Radar dish (inset) is aimed at plane coming in for a landing on aircraft carrier. Signals are converted into speed indications on Raytheon equipment in front of Landing Signal Officer, who by his wig-wag flags can tell pilot whether he is coming in at safe landing speed

Airborne TV Broadcast

A novel approach to TV broadcasting was made in San Francisco when "Exclusively Yours" program originated from a giant Douglas C-124 Globe-master plane as it circled about 3,000 feet above the Bay Area. Program was seen over KRON-TV. Contact with the ground was by means of a special microwave link.



Part of KRON-TV's crew at open hatch of plane ready to beam TV picture to ground. Shown are (l to r) Chief Engineer L. Berryhill, A. Kohn, J. Mooney (kneeling), F. Street, and R. Woodruff (kneeling)

Flight Simulators in Production

Headed by Gen. Benjamin W. Chidlaw, Commanding General, Air Defense Command, a group of high government and military officials recently reviewed the mass-production facilities installed at the Union Switch & Signal division of Westinghouse Air Brake Co. for the assembly of the U. S. Air Force F-86D flight simulators.

Pilot practices using instruments and radar controls in trainer simulating F-86D Sabrejet

The model being produced is a control-for-control, cockpit reproduction of an improved version of the F-86 Sabrejet. Used both as a trainer for new pilots and as a proficiency aid for the more experienced, the simulator infallibly reproduces—with sound effects—almost all the conditions and hazards the Air Force Pilot encounters. Over 25 miles of wire, some 1300 vacuum tubes, and 300 separate chassis assemblies are used in the construction of each simulator.

RCA Color TV Circuits Available

RCA has announced that is making available to its licensees full design and performance details on its color TV receiver. Developmental kits are also being offered.

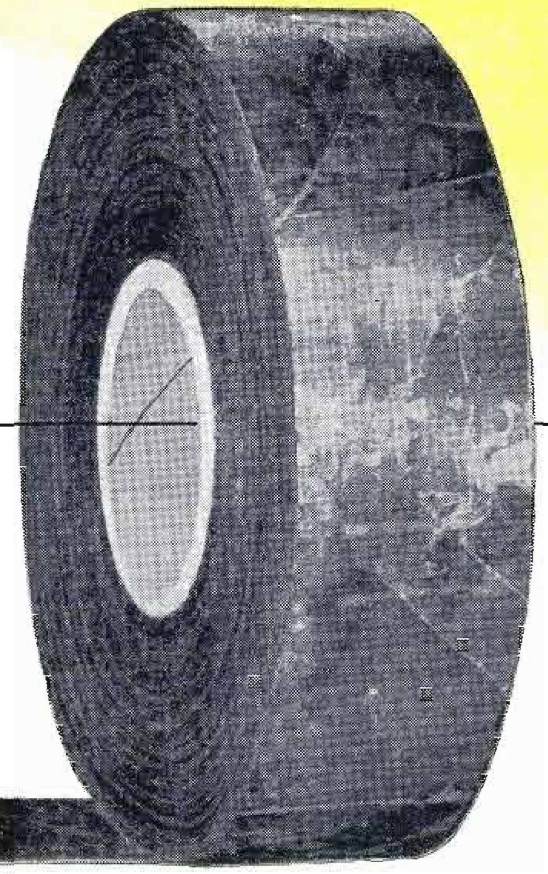
NPA Successor Set Up

The Department of Commerce has set up a new organization—the Business and Defense Services Administration—to continue the remaining mobilization functions of the former National Production Authority, and to consolidate the activities of five current offices in the Commerce Department. Among the 25 industry divisions within the new BDSA is the Electronics Division headed by Acting Deputy Director Donald Parris.

MORE NEWS on page 17

GOT AN INSULATING PROBLEM?

TAPE IT WITH MICABOND



C-D-F, expert in insulation, uses superior grades of mica, places it for complete leak-proof coverage, and applies strong, pliable electrical insulating binders. All Micabond Tapes are hand laid. The large India mica splittings used retain their electrical insulating properties at elevated temperatures.

GRADE 20 — **PAPER BOTH SIDES**

All edges overlapped, faced on each side with strong, tough tissue paper. Flexible binder will not dry out under ordinary conditions. Thickness .005″, .007″.

GRADE 21 — **COTTON CLOTH ONE SIDE, PAPER ONE SIDE**

Bonded with flexible binder. Backed on one side with thin cotton insulation cloth, faced with tissue paper on other side. High tensile strength. Good tear resistance. Use where moderate high voltages are encountered, where space is not limited. Thickness .006″, .008″.

GRADE 22 — **CELLOPHANE BOTH SIDES**

Faced on both sides with .001″ thick moisture-proof cellophane. Unusually high tensile and dielectric strengths. Not quite so pliable. Thickness .005″, .007″.

GRADE 24 — **SILK ONE SIDE, PAPER ONE SIDE**

Bonded with flexible insulating cement. Backed with .001″ silk, and faced with tissue paper on other side. Silk gives tape good tensile and tear strength. Good dielectrically, this tape meets all normal requirements. Thickness .005″, .007″.

GRADE 28 — **SILK BOTH SIDES**

Bonded with flexible, non-slipping binder. Thin silk is used for facing on both sides. High tensile strength. Fine tear resistance. Excellent dielectric strength. The ideal tape for ease of application . . . use where space is limited. Thickness .005″, .007″.

Silicone Bond, Fiberglas cloth one or both sides for class H insulation. This inorganic tape withstands temperatures 50°C—75°C higher than organic bonded material. Thickness .004″, .006″.

Write now for Micabond Catalog. Call your C-D-F sales engineer (sales offices in principal cities). His special knowledge and experience will help save you time and money. He's a good man to know!

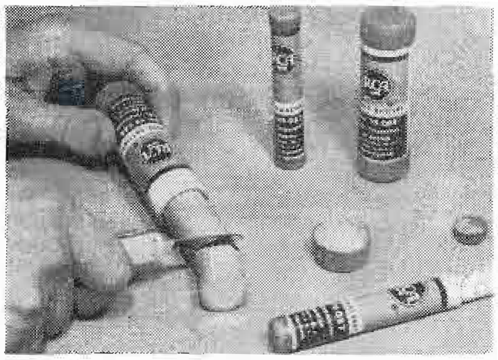
THE NAME TO REMEMBER CDF MICABOND

Continental-Diamond Fibre Company

NEWARK 101, DELAWARE

As We Go To Press . . . *(Continued)*

Slice-Away Batteries for Transistor Use

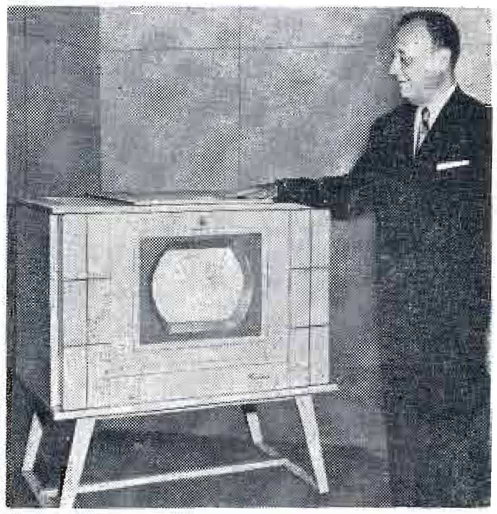


"Slice-Away" battery assemblies for transistor use can be sliced into numerous combinations of odd-lot voltage supplies. Both assemblies are 21-volt special-purpose types containing 15 individual 1.4 volt crown-type alkaline dry cells

Two novel types of RCA alkaline battery assemblies which can be sliced, like a package of candy mints, into numerous combinations of cells to provide different voltage requirements were announced by the Tube Department of the RCA Victor Div. The unusual battery assemblies are intended specifically for equipment designers and experimenters exploring application possibilities of transistors. These battery assemblies are expected to facilitate transistor-circuit experiments because they permit rapid assembly of power supplies not readily available in standard commercial batteries.

Both RCA "slice-away" battery assemblies (VS087, up to 2 ma and VS088, up to 10 ma) are 21-volt special-purpose types. Each contains 15 individual 1.4-volt crown-type alkaline dry cells firmly encased in a plastic sleeve. Each cell is indicated by a pair of ridges which are formed in the plastic sleeve by the scalloped edges of the metal caps of the cell. Various power requirements from 1.4 volts to 21 volts, can be obtained quickly by slicing a section having the necessary number of cells.

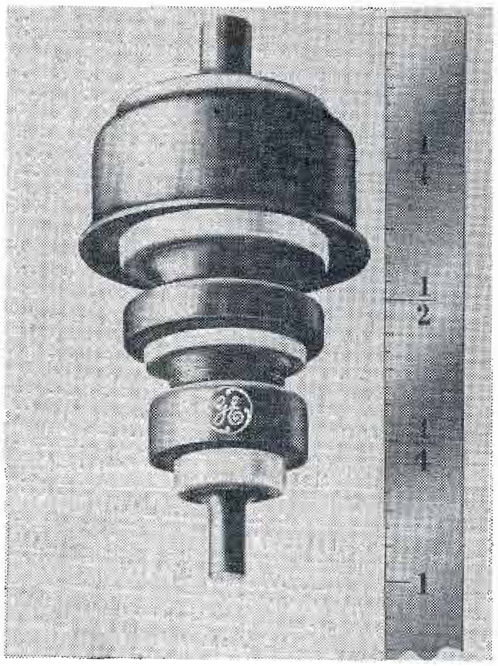
COLOR TV RECEIVER TO GO ON SALE



Benjamin Abrams, President of Emerson Radio and Phonograph Corp., is shown with the set reported to be the first commercial compatible color TV receiver styled for home use and designed for mass production. This Model C-500, a console ensemble with a 16-inch tube providing a 14-inch picture, will be sold for $700 soon after system approval by the FCC

Low-Noise Radar Tube

A new metal-and-ceramic receiving tube, with a noise figure of 8.5 db or better, and a power gain of 16 db at 1200 MC has been developed by General Electric. The tube, type GL-6299 is designed to offer a solution to some of the military UHF high noise-level problems in lower frequency radar equipment. It is a co-planar triode designed specifically for use as a low-level Class A r-f amplifier operating at frequencies as high as 3000 MC. It is 1 in. long, weighs 1/6 oz., and is gold-plated.



Co-planar triode for 3000-MC operation

Other applications of the tube may be made in aircraft communications circuits, in radiosonde receivers, and in UHF beacons and beacon receivers. At 400 MC, a noise figure of 4 to 5 db is obtainable. The tube also has a wide variety of non-military applications.

TELE-TIPS
Begin on Page 52

COMING EVENTS

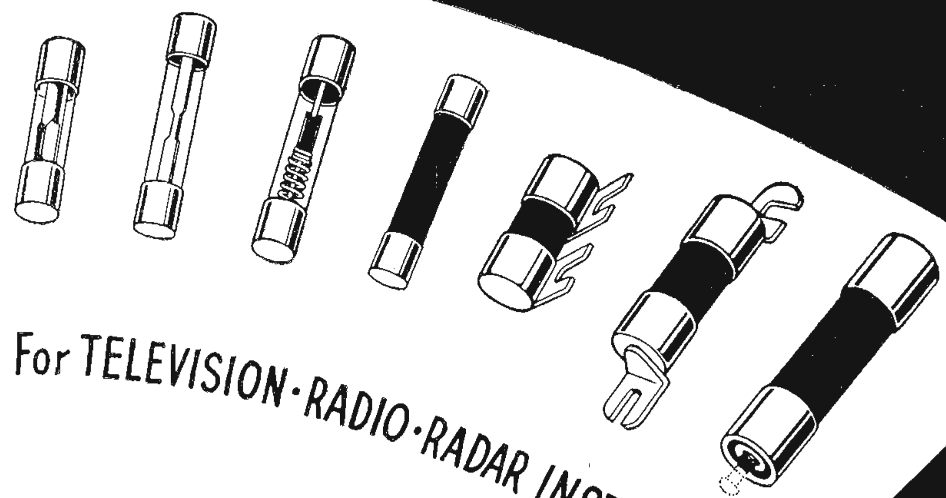
1953

- Nov. 2-6—**AIEE, Fall General Meeting,** Muelebach Hotel, Kansas City, Mo.
- Nov. 4-6—**17th Annual Time and Motion Study and Management Clinic, sponsored by IMS,** Sheraton Hotel, Chicago, Ill.
- Nov. 9-12—**Conference on Radio Meteorology,** Univ. of Texas, Austin, Texas.
- Nov. 12-13—**IRE Professional Group on Vehicular Communications,** Hotel Somerset, Boston, Mass.
- Nov. 13-14—**IRE Annual Electronics Conference,** Hotel President, Kansas City, Mo.
- Nov. 17-19—**RTMA,** Palmer House, Chicago, Ill.
- Nov. 18-20—**AIEE-IRE, Conference on Electronic Instrumentation in Nucleonics and Medicine,** Hotel New Yorker, New York, N.Y.
- Dec. 8-10—**AIEE-ACM-IRE, Eastern Computer Conference,** Statler Hotel, Washington, D.C.

1954

- Jan. 18-22—**AIEE Winter General Meeting,** Hotel Statler, New York, N.Y.
- Jan. 25-27—**Plant Maintenance & Engineering Conference,** Hotel Conrad Hilton, Chicago, Ill.
- Jan. 25-28—**Plant Maintenance & Engineering Show,** International Amphitheatre, Chicago, Ill.
- Jan. 27-29—**Tenth Annual Technical Conference of the Society of Plastics Engineers,** Royal York Hotel, Toronto, Can.
- Mar. 15-19—**NACE Tenth Annual Conference and Exhibition,** Kansas City.
- March 22-25—**IRE National Convention,** Waldorf-Astoria Hotel and Kingsbridge Armory, New York, N. Y.
- April 24—**Eight Annual Spring Technical Conference,** IRE Cincinnati Section.
- April 26-30—**Tenth Biennial ASTE Industrial Exposition,** Philadelphia Convention Center, Phila., Pa.
- May 4-7—**1954 AWS National Spring Technical Meeting,** Hotel Statler, Buffalo, N.Y.
- May 5-7—**AIEE Northeastern District Meeting,** Schnectady, N.Y.
- May 5-8—**1954 Welding and Allied Industry Exposition,** Memorial Auditorium, Buffalo, N.Y.
- May 7-9—**AFCA National Convention,** Shoreham Hotel, Washington, D.C.
- June 21-25—**AIEE Summer General and Pacific Meeting,** Hotel Biltmore, Los Angeles, Calif.

AFCA: Armed Forces Communications Ass'n.
AIEE: American Institute of Electrical Engineers.
ASTE: American Society of Tool Engineers.
AWS: American Welding Society
IMS: Industrial Management Society.
IRE: Institute of Radio Engineers
NACE: National Association Corrosion Engineers.
RETMA: Radio-TV Manufacturing Association.



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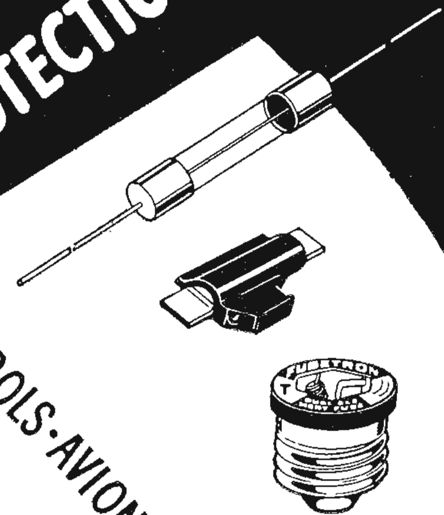

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They will gladly help you select the fuse that suits your needs best . . . if possible, a fuse available from local wholesalers' stocks.

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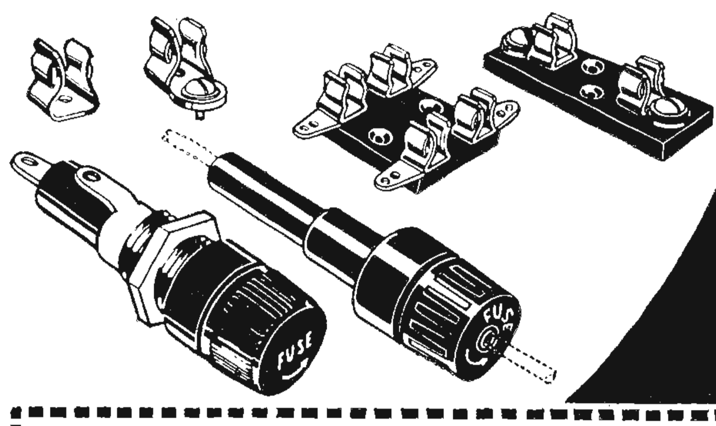

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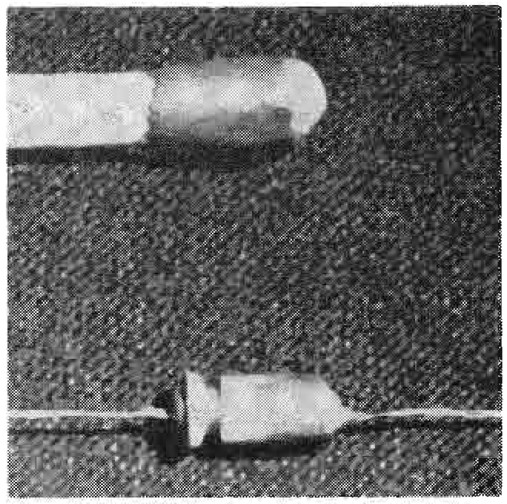
As We Go to Press . . . .

New Tantalum Capacitor Companion For Transistor

A tiny tantalum capacitor, one of the smallest high capacity units ever designed for low voltage, dc applications, has been announced by General Electric. It will make possible further size reductions in miniaturized assemblies using transistors. The new unit measures 5/16 in. long and 1/8 in. in diameter.

The unit is sealed against leakage or contamination and utilizes a non-acid electrolyte. It is designed to operate over a temperature range of −20° C to +50° C and is suitable for



New tantalum capacitor is compared here with a wooden match. It has a diameter of 1/8 in. and a length of 5/16 in., and is the first in a new line of "micro-miniature" capacitors for miniaturized equipment

storage at −65° C. The new unit is available in ratings from 2 to 16 volts, 4 to 0.7 μf respectively. Another, larger capacitor, 0.5 in. long with similar characteristics and the same voltage range, but with 8 to 1.5 μf, has also been announced as available.

The capacitors have a tantalum anode oxidized to the voltage rating, enclosed in a silver case, and impregnated with non-acid solution. A synthetic plug in the end of the case is roll-crimped into place and a solderable tin-coated nickel lead is lap-welded externally to the projecting tantalum anode lead, permitting connection up to the case. The case itself is the cathode, and is equipped with a tin-coated copper lead soldered to the case. The units are of the polarized type.

A LETTER

describing one of the early uses of the word "electronic" in Germany appears on page 30

LETTERS...

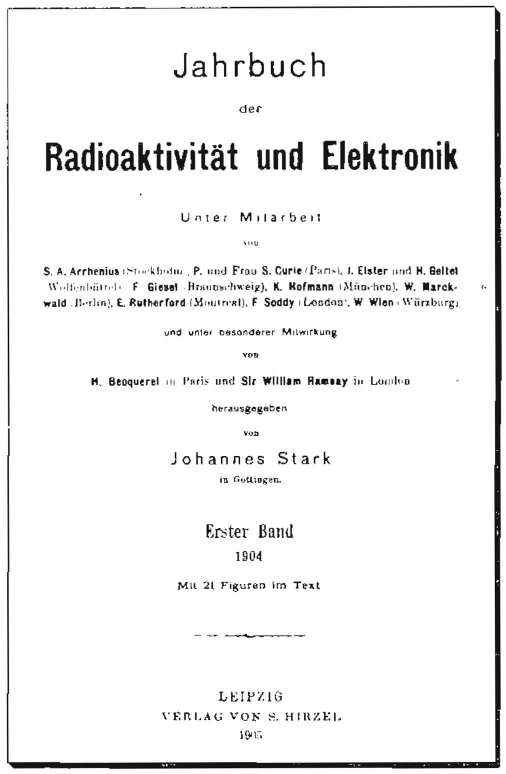
First Uses of the Term "Electronic"

Editors, TELE-TECH:

I just had a chance to see the short feature "Electronic" First Uses in 1832 and 1929 in Tele-Tech May 1953 on page 60-61.

You might like to know that the noun "Elektronik," the German equivalent of "Electronics" was part of the title of a German periodical "Jahrbuch der Radioaktivität und Elektronik," which easily translates into "Yearbook of Radioactivity and Electronics" of which 20 volumes appeared, published during the years 1905-1924.

As you see from the enclosed photostat of the title page of the first volume of the "Jahrbuch" the board of editors



Jahrbuch

der

Radioaktivität und Elektronik

Unter Mitarbeit

von

S. A. Arrhenius (Stockholm), **P.** und Frau **S. Curie** (Paris), **J. Elster** und **H. Geitel** (Wolfenbüttel), **F. Giesel** (Braunschweig), **K. Hofmann** (München), **W. Marckwald** (Berlin), **E. Rutherford** (Montreal), **F. Soddy** (London), **W. Wien** (Würzburg)

und unter besonderer Mitwirkung

von

H. Becquerel in Paris und **Sir William Ramsay** in London

herausgegeben

von

Johannes Stark

in Göttingen.

Erster Band

1904

Mit 21 Figuren im Text

LEIPZIG
VERLAG VON S. HIRZEL
190[illegible]

consisted of distinguished scientists, as Monsieur and Madame Curie, Lord Rutherford, P. Becquerel, and other people of international fame.

Unfortunately, this first volume of the "Jahrbuch" does not contain a foreword in which the term "Elektronik" is exactly being defined, nor is anything said about its origin.

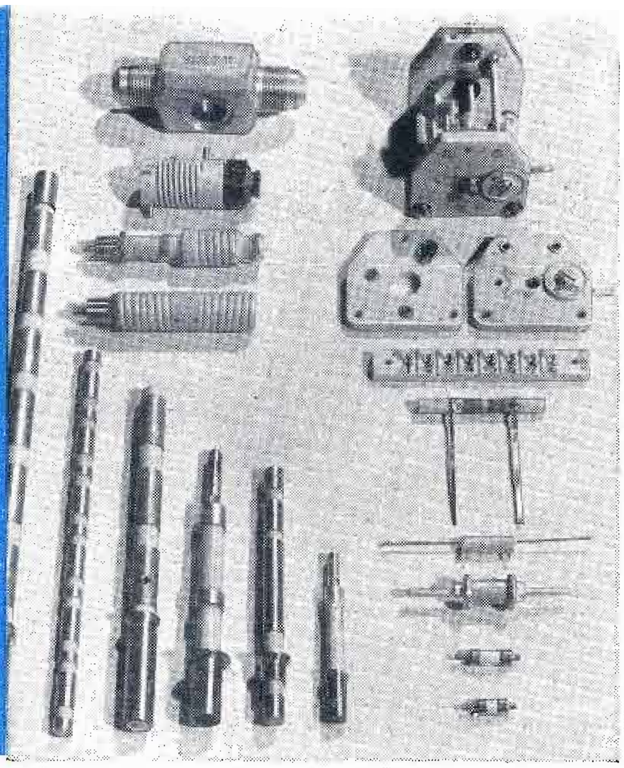
The word "Elektronik" in the sense as it is now being applied to electronic art has only very recently been introduced into German usage. It is most likely that this time it has been adopted from the English term "Electronics."

HELMUT DRUBBA

Schrötteringksweg 9
(24a) Hamburg 21, Germany

TELE-TIPS
begin on page 52

ceramics and metal are permanently and accurately combined



The metal bands on the rotor shafts shown at the left, above, are concentric with the shaft to within 0.001 in.

Stupakoff assemblies

Your production procedure is simplified when you use high-precision Stupakoff ceramic-to-metal assemblies. Extensive experience in the field of electrical and electronic ceramics, thorough familiarity with methods of metallizing, and the use of modern precision manufacturing methods insure the high quality and uniformity of Stupakoff Assemblies.

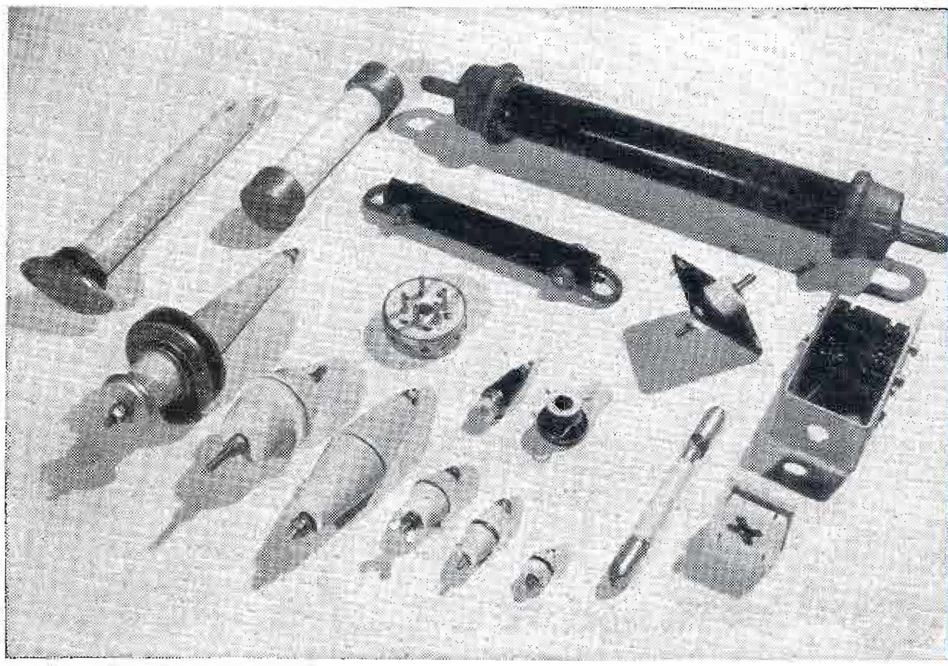
Among the assemblies made by Stupakoff are: rotor shafts, strain and spreader insulators, stand-offs and trimmers. Ceramic bodies are specially formulated for the intended service; metals used include silver, copper, brass, stainless steel and monel. Stupakoff's broad experience in this field insures the selection of a method of assembly best suited to meet service conditions.

A few types of Stupakoff Ceramic-to-Metal Assemblies are illustrated in the photographs on this page.

STUPAKOFF CERAMIC & MANUFACTURING COMPANY

LATROBE, PENNSYLVANIA

Some of the larger types of Stupakoff metallized ceramic parts.



Small metallized ceramic parts are accurately made and dependably uniform.

TELE-TIPS

NEW CAMERA for photographing microscopic particles (aerosols) floating free in the atmosphere has been announced by Stanford Research Institute. The camera's depth of field is 200 microns (a micron is 1/25,000 in.). Instead of a mechanical shutter, pulsed flashes of a narrow-beam light provide the film exposure. The flashes—of 2,000,000 candlepower intensity—may be 1, 4, or 10 μsecs. duration. In a "pea-soup" fog, scientists have counted up to 2,000 aerosol particles per cu. in. The camera may make it possible for the first time to follow and record the history of an unstable aerosol particle over a short period.

TV OVERSEAS—In many small French communities they have tele-clubs; the whole village contributes to the cost of the TV receiver, which is set up in the local schoolhouse, and in the evening everybody comes in to watch and listen. . . . In West Germany, a new kind of video show is planned—the "commercial hour." Early in the evening, before the regularly scheduled show starts, all the advertising commercials will be put on for from one-half to a full hour. Then, the evening entertainment show will go on without interruption, right up to the sign-off time. . . . In England recently, tax collectors were checking for unlicensed TV sets. They found a great number of people had antennas on their roofs but no TV sets downstairs. Reason was to make TV-equipped neighbors think they had them, too. Incidentally, the license for a TV receiver there costs $5.70 a year.

HOUSE-METER READING—Dr. W. R. G. Baker of GE predicts that one of the major increases in the use of electronics will be in industry—and indicates that a result may be to eliminate one of the solid institutions of the electrical age, the man who reads the meter. He said that household watt-hour meters may be read electronically. The information would be transmitted automatically to electronic business machines which would make out bills and compile a complete record.

(*Continued on page* 54)

TELE-TIPS

(Continued from page 52)

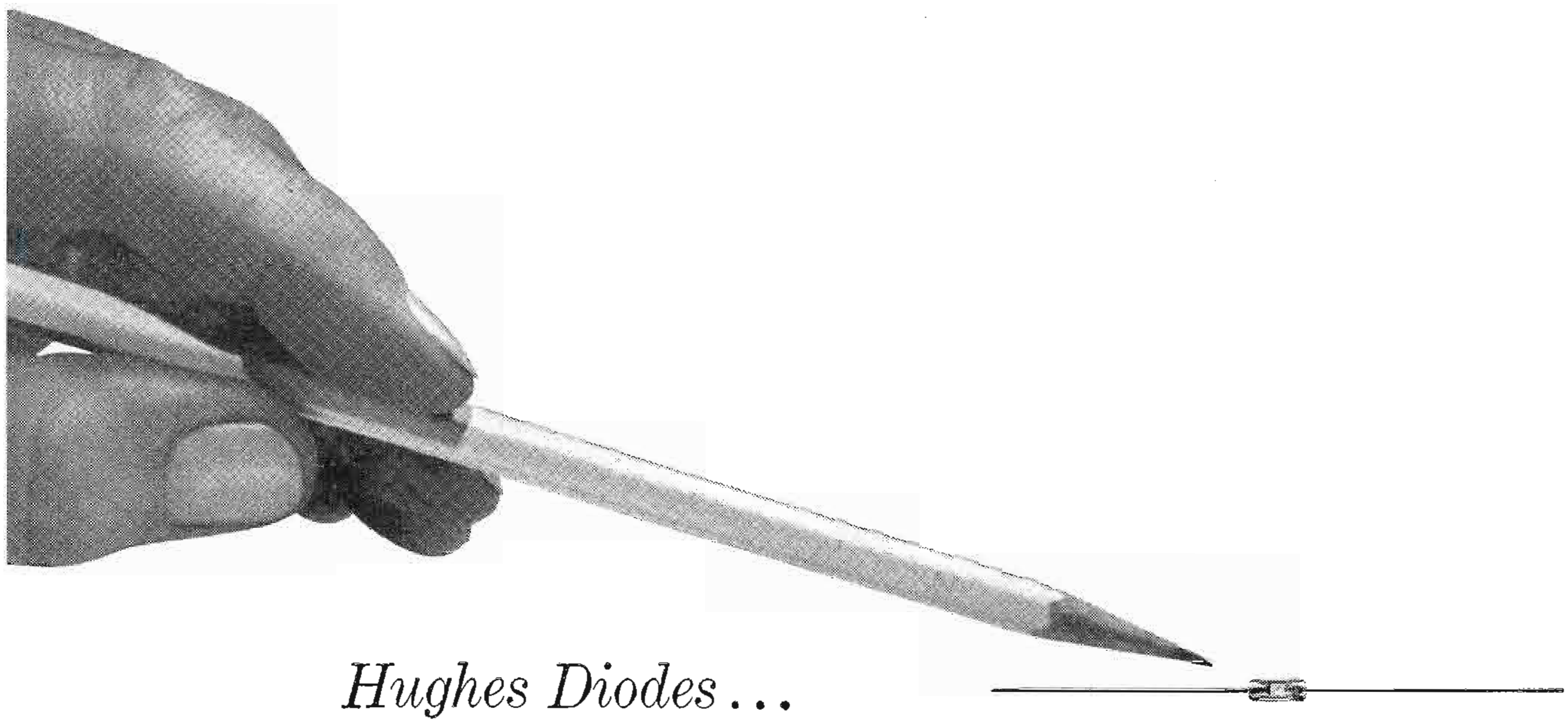
FROM BEHIND THE IRON CURTAIN comes grim evidence of the prostitution of the engineering profession to serve the ends of political propaganda. As reported in the *General Electric Review* by P. A. Abetti, the widely read Russian electrical engineering magazine, *Elektrichestvo,* constantly keynotes the Communist party line and ruler glorification.

A typical lead was the one carried in the Nov. 1951 issue: "Bolshevism is the power of the Soviets, plus electrification of the whole country. . . . Under the banner of Lenin, under the leadership of Stalin—forward to the victory of Communism! . . . Soviet science is the most progressive in the world. . . . " Then comes denunciation of project failures and individual engineers: "Training of the younger scientific workers by the staff of the Institute is at the lowest level, due to the guilt of the directors of the laboratories (I. S. Bruk, S. F. Chukov, M. B. Ravic, and others). . . ."

References to foreign articles are often omitted, and reviews of technical papers, particularly American, are often incorrect and politically biased. Although illustrations are sparingly used, *Elektrichestvo* carried a full-color portrait of Stalin on his 70th birthday. The East German *Elektrotechnik* is louder still in its brassy praise for the Soviet masters. Even the Yugoslavian book, *Transformation and Transmission of Energy,* speaks of "the capitalistic robber-transformer" which has higher losses (and greater profit for the manufacturer at the customer's expense) than the socialist transformer.

AIR CONDITIONING in industrial plants means more than employee comfort. As will be demonstrated at the Refrigeration and Air Conditioning Exposition in Cleveland, Nov. 9-12, correct temperature and humidity can improve production and reduce costs.

(Continued on page 58)



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Reliability in a germanium diode is determined principally by permanent freedom from the two major causes of diode failure—moisture penetration of the diode envelope, and electrical instability under extreme operating conditions.

HUGHES GERMANIUM DIODES are designed to prevent such failures through two exclusive features:

1. **Fusion Sealing**—The glass-to-metal seal, proved in billions of vacuum tubes, is incorporated to full advantage in diode manufacture by the Hughes-developed process of fusion sealing at high temperature. The result is a rigid *one-piece* glass envelope impervious to moisture.

2. **100% Testing**—Hughes 100% testing procedures *invite* instabilities to occur prior to shipment, assuring rejection of every defective diode. *Each* **HUGHES DIODE** is humidity-cycled, temperature-cycled, JAN shock-tested, and electrically tested under vibration. This testing procedure insures the operation of **HUGHES DIODES** under adverse conditions of moisture, temperature, vibration and severe shock.

Reliability of **HUGHES DIODES** has been proved in airborne military electronic equipment for navigation, fire control, and guided missiles.

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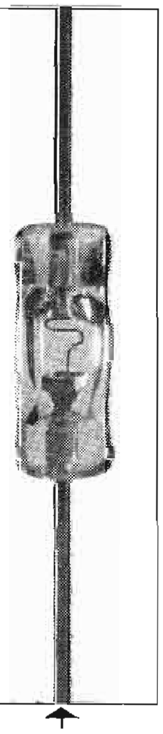
Description	RETMA Type	Test Peak Inverse Voltage* (volts)	Maximum Inverse Working Voltage (volts)	Minimum Forward Current @ +1 v (ma)	Maximum Inverse Current (ma)
High Peak	1N55B	190	150	5.0	0.500 @ −150 v
	1N68A	130	100	3.0	0.625 @ −100 v
High Back Resistance	1N67A	100	80	4.0	0.005 @ −5 v; 0.050 @ −50 v
	1N99	100	80	10.0	0.005 @ −5 v; 0.050 @ −50 v
	1N100	100	80	20.0	0.005 @ −5 v; 0.050 @ −50 v
High Back Resistance	1N89	100	80	3.5	0.008 @ −5 v; 0.100 @ −50 v
	1N97	100	80	10.0	0.008 @ −5 v; 0.100 @ −50 v
	1N98	100	80	20.0	0.008 @ −5 v; 0.100 @ −50 v
High Back Resistance	1N116	75	60	5.0	0.100 @ −50 v
	1N117	75	60	10.0	0.100 @ −50 v
	1N118	75	60	20.0	0.100 @ −50 v
General Purpose	1N90	75	60	5.0	0.800 @ −50 v
	1N95	75	60	10.0	0.800 @ −50 v
	1N96	75	60	20.0	0.800 @ −50 v
JAN Types	1N126**	75	60	5.0	0.050 @ −10 v; 0.850 @ −50 v
	1N127†	125	100	3.0	0.025 @ −10 v; 0.300 @ −50 v
	1N128‡	50	40	3.0	0.010 @ −10 v

*That voltage at which dynamic resistance is zero under specified conditions. Each Hughes Diode is subjected to a voltage rising linearly at 90 volts per second.

**Formerly 1N69A. †Formerly 1N70A. ‡Formerly 1N81A.



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In addition to RETMA-*registered types,* HUGHES DIODES *are also supplied 100% factory-tested to a wide range of customer specifications, including high-temperature requirements.*

FUSION SEALED IN GLASS *for electrical stability*

TELE-TIPS

(*Continued from page 54*)

GLASS-CLOTH WAVEGUIDES—Lee Laboratories of Genesee, Pa., have completed development work on a new technique for making waveguide parts, and are in a position to supply sample fabricated components. The new method uses a glass-cloth base and eliminates all soldering, brazing, etc. normally required with brass or aluminum waveguide. Weight and strengthwise, the glass-cloth waveguide is equal to aluminum tubing. The major feature of these new components is the fabrication simplicity which reduces the manufacturing costs. Important savings can be realized in making complicated structures where normally, tools and fixtures are needed to hold tolerances while brazing. All types of microwave transmission components can be made by this new method, directional couplers, duplexers, mixers, etc.

BROADCASTING TERMINOLOGY was given a new twist by Harold E. Fellows, NARTB president. For the enlightenment of the wives of radio and TV personnel, he recently made the following tongue-in-cheek definitions:

FCC: A secret society, directed by six men and one woman, intent upon determining the public interest and convenience of your husband, but not his necessity.

Commercial Manager: The fellow after the manager's job.

General Manager: An all-suffering martyr who is trapped by circumstance and must carry on in the face of all odds.

Rate Cut: Something being done by the competitor across the street.

Network (if husband's station is unaffiliated): An organized effort to eliminate independents.

Network (if husband's station is affiliated): An organized effort to create independents.

CONFUSION REIGNS—A recent applicant for a position at Emerson was handed an employment application to fill out. In answer to the question, "DRAFT STATUS?", he wrote, "Veteran." The next question, "LOCAL BOARD?" His answer, "CIO, Local 475."

TELE-TECH
& ELECTRONIC INDUSTRIES—RADIO-TELEVISION
O. H. CALDWELL, Editorial Director ★ M. CLEMENTS, Publisher ★ 480 Lexington Ave., New York (17) N. Y.

Air Power Future and the Electronic Industry

Let us consider the problems and prospects of the electronic industry in future airpower. The electronic industry has a dual character; it is a major element of our peacetime economy; and it is a vital element of our military potential. The relations between the two roles are sometimes subtle and at other times basic. There can be no doubt that the large amount of military-sponsored research on radar during the war gave a strong impetus to television. But beyond this, the exposure of a large number of young men to electronics in the services, with the training these men received, made it possible for this country to have large numbers of television service men for our peacetime economy. In reverse our large television industry with its tremendous service establishment and hundreds of TV schools provides a pool of highly trained men for a war emergency. In short, the electronic industry as such has a definite dual role.

Recently the Air Force announced a new policy for "Weapon Systems Development" in which one contractor, presumably the airframe manufacturer, is to be given the contractual responsibility for the development of a complete airplane with all its elements. By this means the Air Force is attempting to obtain integrated combat-ready weapon systems. It is in part a recognition of the intimate relationship of the elements that go into a fighting aircraft; but it is also a recognition of the administrative problems which existed when the Air Force itself tried to provide the technical and contractual coordination. It is not at all clear that swinging all the way in the new approach of contracted systems responsibility will either solve these problems, nor is it clear that new ones will not rise to rear their ugly heads.

Dangers in New Policy

Over the long run there are a number of dangers. One of these is the possibility of severance of the intimate intellectual relationship which now exists between the Air Force and the electronic industry. This relationship has been mutually stimulating, and will undoubtedly be reduced by the insulation of dealing through prime contractors. Another possible danger is the growth within the airframe industry of specialized electronic facilities, lacking the advantages of stabilizing peacetime and commercial support. Granting that military expenditures are bound to fluctuate, such facilities become in effect expensive and detract from concept of dual facility plants which Secretary Wilson advocates.

Finally, there is always the danger, and it is particularly evident right at this time, that projects not directly associated with end-item objectives will be cancelled. It is inevitable and proper that prime contractors under the weapon systems concept take the short-time view. They are required to produce an integrated machine in a finite time. Consequently they must start with available building blocks. This incentive toward conservatism will reduce waste but perhaps at the cost of advanced performance. Thus, over the long haul we shall stand to suffer in qualitative superiority unless effective steps are taken to continue direct contracting between the Air Force and the electronics industry not only on new components, and techniques, but also for major elements like fire control systems, auto pilots, and automatic landing systems. It is interesting to note that to date every successful anti-aircraft guided missile, whether ground-to-air or air-to-air, was developed with systems responsibility in an electronic organization.

Must Guard Research and Long-Term Projects

I sincerely hope that the Air Force will approach their new weapons-system contractual policy with care, and that the Air Research and Development Command will continue to improve on channels of communications between contractors and the using branches of the Air Force to provide for better coordination, and to streamline their contractual procedures, and above all that ARDC will zealously guard the long-term projects, and the research programs, and support component developments. The Air Force is unique in having a centralized organization, the ARDC, which can devote its full energies to the task of assuring qualitative superiority. It is a difficult assignment—one which requires an appreciation of the problems not only of the Air Force, but also of industrial and university research organizations. ARDC has made a valiant start through its enlightened policies and it deserves our vote of confidence.

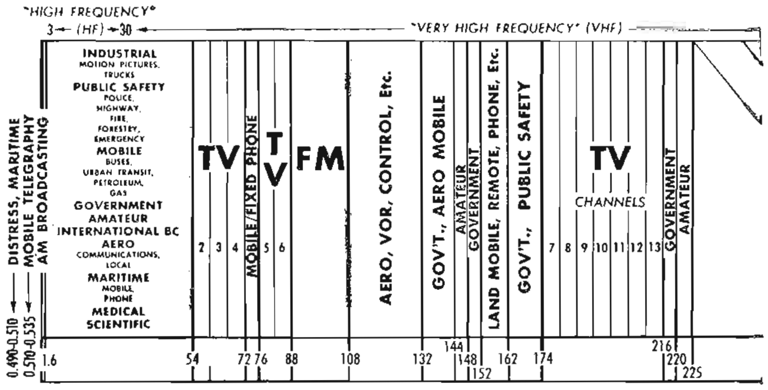
Electronics has much to offer to Airpower Future. With increasing speeds, airplanes become more and more dependent upon electronic flight instruments and controllers; bombs, rockets and guns are useless without radar and electronic computers; all-weather flying and even visual navigation requires electronics. And finally, airpower in the sense of integrated striking and defensive power has no meaning without the "nervous system" provided by electronics.

The future will see the use of smaller components, like transistors, and the introduction of new techniques, such as digital computers. Undoubtedly from a technical view, air-warfare will become a lot more complicated. This will be forced upon us by the capabilities of our enemy. Let us hope that through research and development, we as a nation can meet this challenge for overwhelming qualitative superiority, which President Eisenhower has so clearly stated as our National Policy.

A guest editorial by Dr. Ivan A. Getting, vice-president Engineering & Research, Raytheon Mfg. Co., Waltham, Mass., adapted from an address by Dr. Getting before the Air Force Association, Washington, D.C.

RADARSCOPE

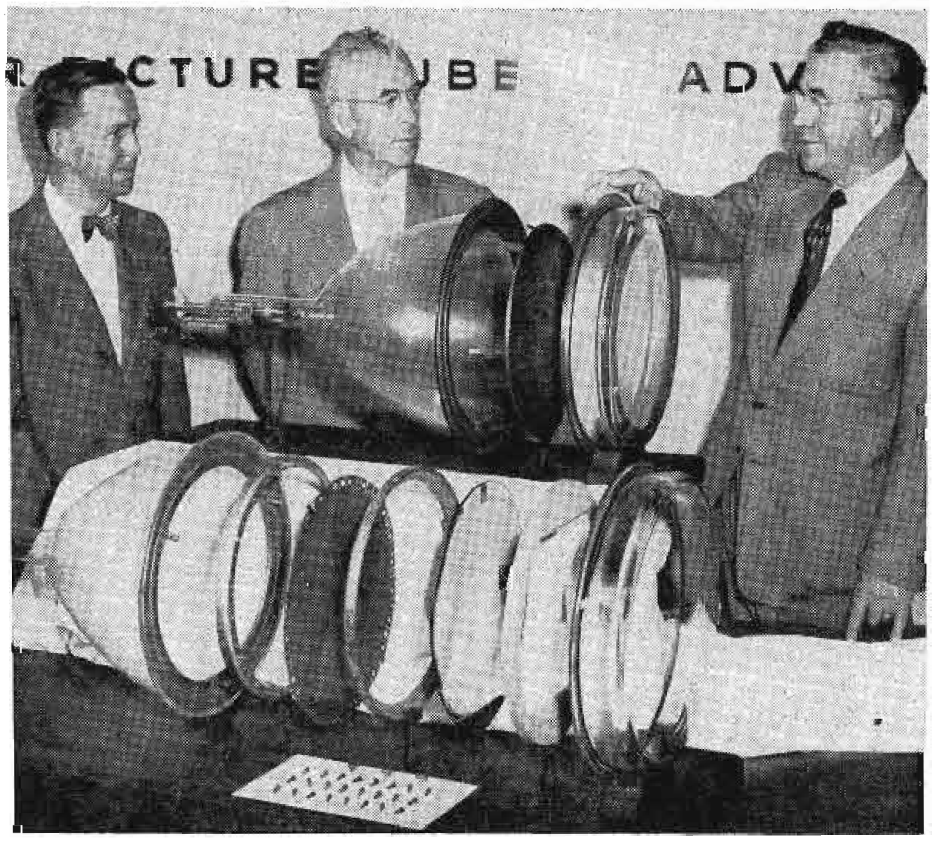
Revealing Important Advances Throughout the Spectrum of Radio, TV and Tele Communications



AUTOMATION

INDUSTRIAL PLANTS with extensive automatic production machinery are making increasing use of electronic control equipment—but are doing so very cautiously. Strong preferences exist for electro-mechanical and pneumatic devices, with electronic units often getting the nod in those cases where, to quote one plant manager, "electronic controls are the only way out." Such "only way out" situations are becoming increasingly frequent, but the root of the wary attitude is based on three factors. (1) Old-line operating management is unfamiliar and suspicious of the precocious electronic baby. This means new markets for sales engineers and educational promotion. (2) Too few qualified electronic personnel to maintain, or even understand, the equipment. Result—new opportunities for experienced electronic engineers. (3) "Tubes mean trouble." A hearty challenge to design engineers to improve reliability.

CBS SHOWS COLOR-TV TUBE



Bruce Coffin, president of CBS-Hytron Div., points to new curved-mask type color tube recently developed by his company. Note constructional simplification achieved over planar-mask type below. The new tube can be built in any of the existing picture tube sizes either round or rectangular. Initial production emphasis, however, will be on popular 21-in. rectangular size. Pilot production models scheduled to be available by Feb. 1954, with full production at new Kalamazoo plant by 1956. Shown with Mr. Coffin are (l) Charles Strohmeyer, vice president, engineering and manufacturing; and Lloyd Coffin, treasurer of CBS-Hytron.

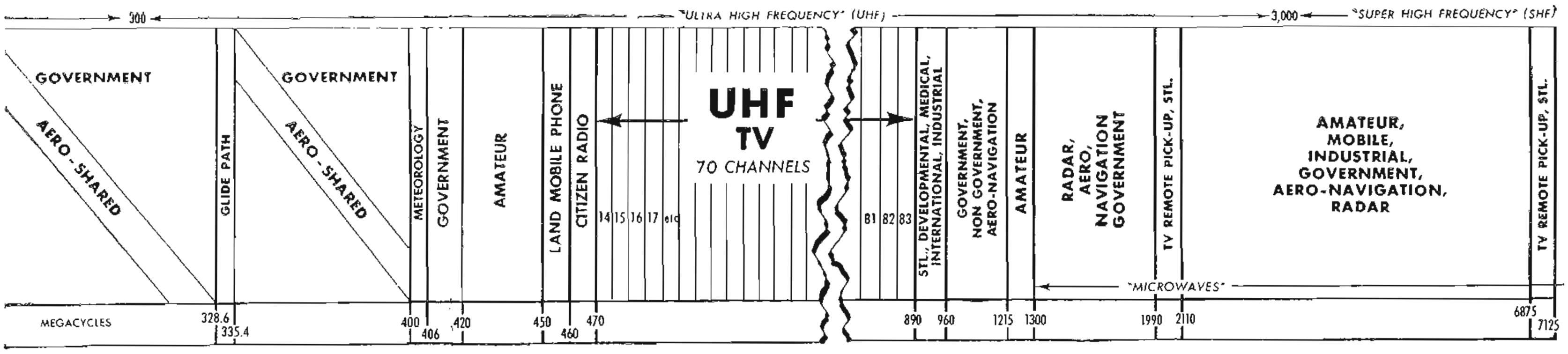
SPECTRUM ALLOCATION

FM MAY LOSE FREQUENCIES to non-broadcast services such as mobile radio if steps are not taken to increase the utilization of the band presently assigned. In a clear warning to FM broadcasters, FCC Commissioner E. M. Sterling stated, "I would have difficulty in finding it in the public interest to retain all of the 88-108 MC band for FM broadcasting in the event the Commission is petitioned to reallocate a portion of the band to accommodate new services or to relieve the congestion in existing services." He also noted that efficient usage of the FM band is not being made, thereby placing the broadcasters in an untenable position with respect to justifying the right to retain all frequencies presently allocated. This observation is of extreme interest to several communications organizations, including the Committee on Manufacturers Radio Use, which plans to petition the FCC in November of this year for the establishment of a manufacturers' radio service.

COLOR-TV

LATEST CBS COMPATIBLE COLOR-TV ADVANCES—Despite the many successful previous color-TV demonstrations, the program demonstrated by CBS last month was disappointing. The quality of the picture was far below that viewed at other demonstrations in connection with NTSC system tests. Just what went wrong is not known, but it should be noted that there were three new color equipment elements used in this demonstration. The first, a camera, uses a single pickup tube instead of the usual three (one for each color). The "old" field sequential scanning method is employed to provide color information for the system.

The second element, a color encoder, translates the field sequential color information into an NTSC compatible color signal. The final element, an improved color tube, employs a curved rather than a planar type mask (see photo at left). Since we had the privilege of viewing the color tube on a closed circuit using NTSC color slides as a signal source, and since the results here were excellent and more than comparable with that noted on tubes of other manufacture, it would appear that the color input equipment was at fault. The "Colortron," as the new tube is called, promises to be a real contribution to future color TV because the manufacturing simplification achieved will permit lower-cost receivers and ultimately more prospective purchasers. For a description of the tube see page 73.



TV ANTENNAS

IN EARLY RADIO DAYS the outside antenna was the sign of a radio receiver—usually a crystal and earphones installation. Already the early days of television have passed and although the 26,700,000 TV receivers now in use have a goodly number of antennas on the roof tops, the number of external antenna installations is steadily decreasing. The effect of greater receiver sensitivity and of raising the effective radiated power of television stations to 200 kw for high-band VHF stations and UHF stations, will be to ease the lot of the apartment dweller who is not allowed to install an external antenna. In fact it will alleviate the situation to such an extent that many threatened court cases will not be heard. Due to poor reception many tenants have been threatening court cases to prove rights to decent TV reception, and the problems involved had promised to demand the talents of a Solomon. Already the new sets and increased powers have rendered outdoor antennas not always necessary. But what will happen when UHF-TV comes to town?

AVIATION

DOUBLE HEAD-SETS with constricting head bands appear to be about passé for airplane pilots. Hearing-aid principles have now been applied to a new miniature earphone, similar to those used in hearing aids, but especially designed to be more rugged and to have a response suitable for use in communications systems. Weighing only two and one-half ounces, the complete assembly is twelve times more sensitive than unconventional ear phones! The new phone is used with only one ear, thus leaving the other available for cockpit conversation. It seems as though the days of the dashing air force pilot with down-bent sides to his cap (caused by pressure of the double head set) are over!

GUIDED MISSILES

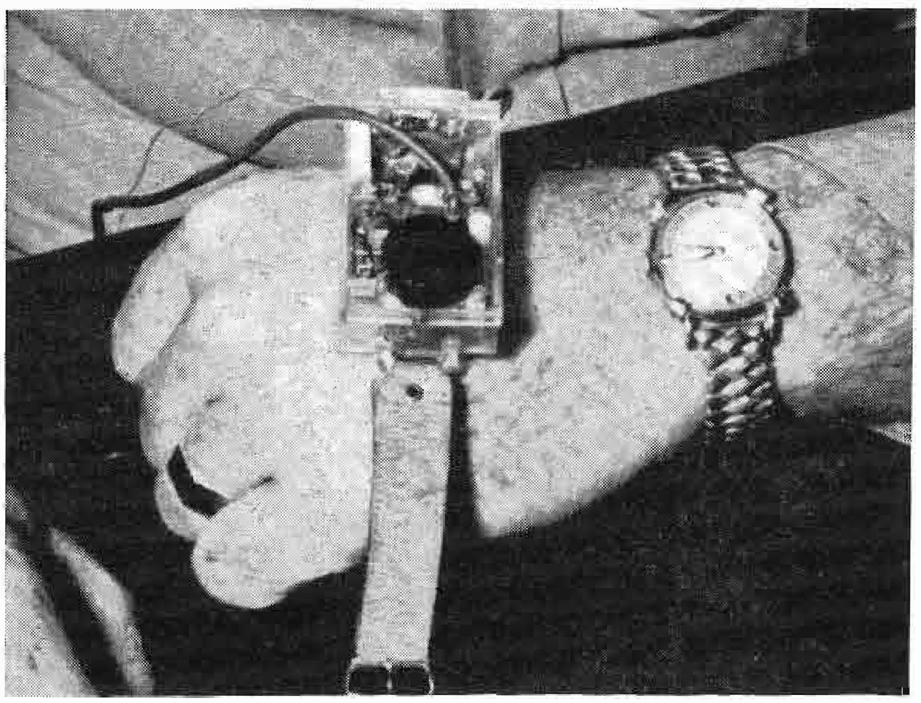
HIGH TEMPERATURES encountered by supersonic aircraft and guided missiles is one of the key problems facing aerodynamicists today. Heating is caused by the temperature rise of the air near the surface of a high-speed vehicle, a result of skin friction between the exterior surface of the vehicle and the air. This barrier is not a well defined speed region, as is the sound barrier, but is an ever increasing obstacle to higher flight speeds. The temperature rise, for example, with an aircraft flying at 1000 mph would be 230° F, and 800° F at 2000 mph. The effect on internal equipment, and particularly electronic units which have been miniaturized into very small spaces, is highly critical. To speed developments in the aircraft and guided missile field, an Industry Advisory Committee on equipment cooling systems has been set up to provide guidance to specialists at the Air Research and Development Command's Wright Air Development Center.

ATOMIC RADIO

NUCLEAR EXPLOSIONS such as the great new stars or "novas" which occasionally burst out in the sky, are now being shown to be sources of radio emissions picked up by the new radio telescopes. In a recent issue we pointed out how the site of Tycho Brahe's great nova of 400 years ago is still today a source of radio noise—also it is known that the Taurus "radio star" of 1953 coincides in position with the Crab nebula, remnant of a galactic supernova recorded in the Orient in A. D. 1054.

One of the most intense radio sources is in Cassiopeia at $23^h\ 21^m .2, +58°\ 32'$ (1950), where Dewhirst and Baade have photographed faint nebulosity. The Russians find that this is in a region where Chinese astronomers observed a new star for six months in the year 369. While the ancient record of this object is brief and vague, it appears to indicate a supernova rather than an ordinary nova.

WRIST-WATCH RADIO



Finally, after many predictions of wrist-worn radios in science fiction, here's the real thing as developed by the United States Signal Corps. Picture shows hand of Captain M. G. Bourgeois, Chief of New Equipment Special Activities division headquarters. Signal Corp Electronic Laboratories, for comparison of the new wrist-type printed-circuit radio receiver, with a standard wrist watch for size.

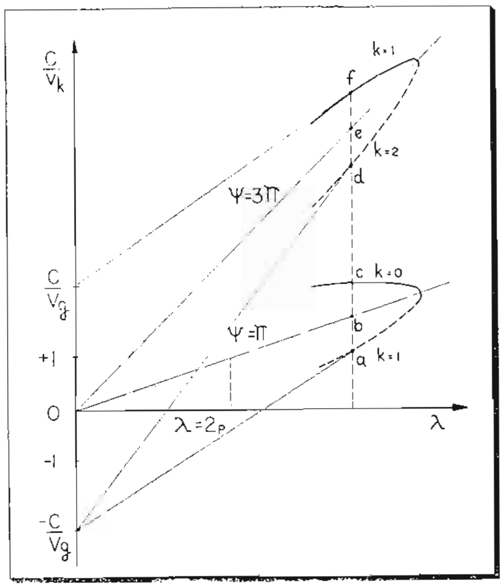


Fig. 1: Dispersion in a periodic delay line

"Carcinotron"—Backward

DURING the last few years the backward wave oscillator has been systematically investigated in France under the name "Carcinotron." In June, 1952, B. Epsztein[1] announced that one of these Carcinotrons, operating at S-band, had delivered continuous output power of more than 100 watts and had been electronically tuned over a 30% range. Recently R. Warnecke and P. Guénard[2] commented on the physical principles of these oscillators and reported on the results ob-

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tained with experimental models. The French authors have defined two kinds of Carcinotrons, the O type and the M type. The O type broadly includes the tube described by R. Kompfner[3] and bears a resemblance to traveling wave amplifier tubes,[4] which may employ a magnetic field for beam focussing purposes. The M type requires a transverse magnetic field for its operation, and bears a resemblance to the magnetron type traveling wave amplifier.[5,6] This paper is primarily concerned with an M type tube.

Both the O and M type oscillators depend for their operation on the interaction between a beam of electrons traveling at a velocity associated with the phase velocity of a traveling wave space component moving in a direction opposite to that of the energy flow along a wave propagating structure. Such structures are delay lines of the periodic filter type having suitable properties.

The properties of delay lines having a periodic structure have been summarized by Guénard et al,[7] in the following convenient form:

"If, in an infinitely long periodic structure (i.e. such that it coincides with itself when translated any integral number of times by the pitch, p) one transmits energy at a given frequency, the distribution of the electromagnetic field along the line likewise has a periodic structure; in a definite manner, the complex amplitudes of the fields at two corresponding points A_0 and A_n of two cells separated by n times the pitch are such that:

$$E_n = E_0 e^{-jn\psi} \quad (1)$$

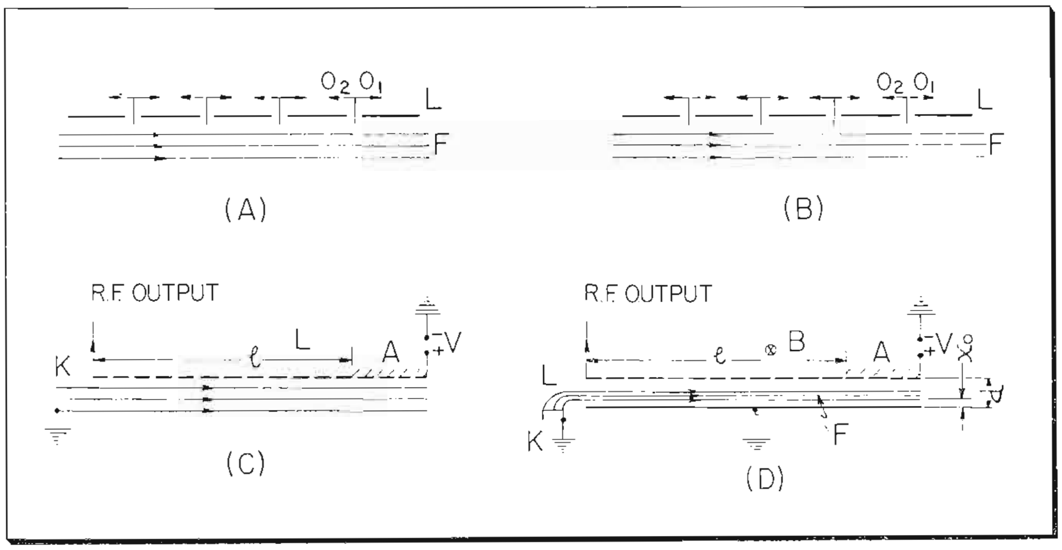
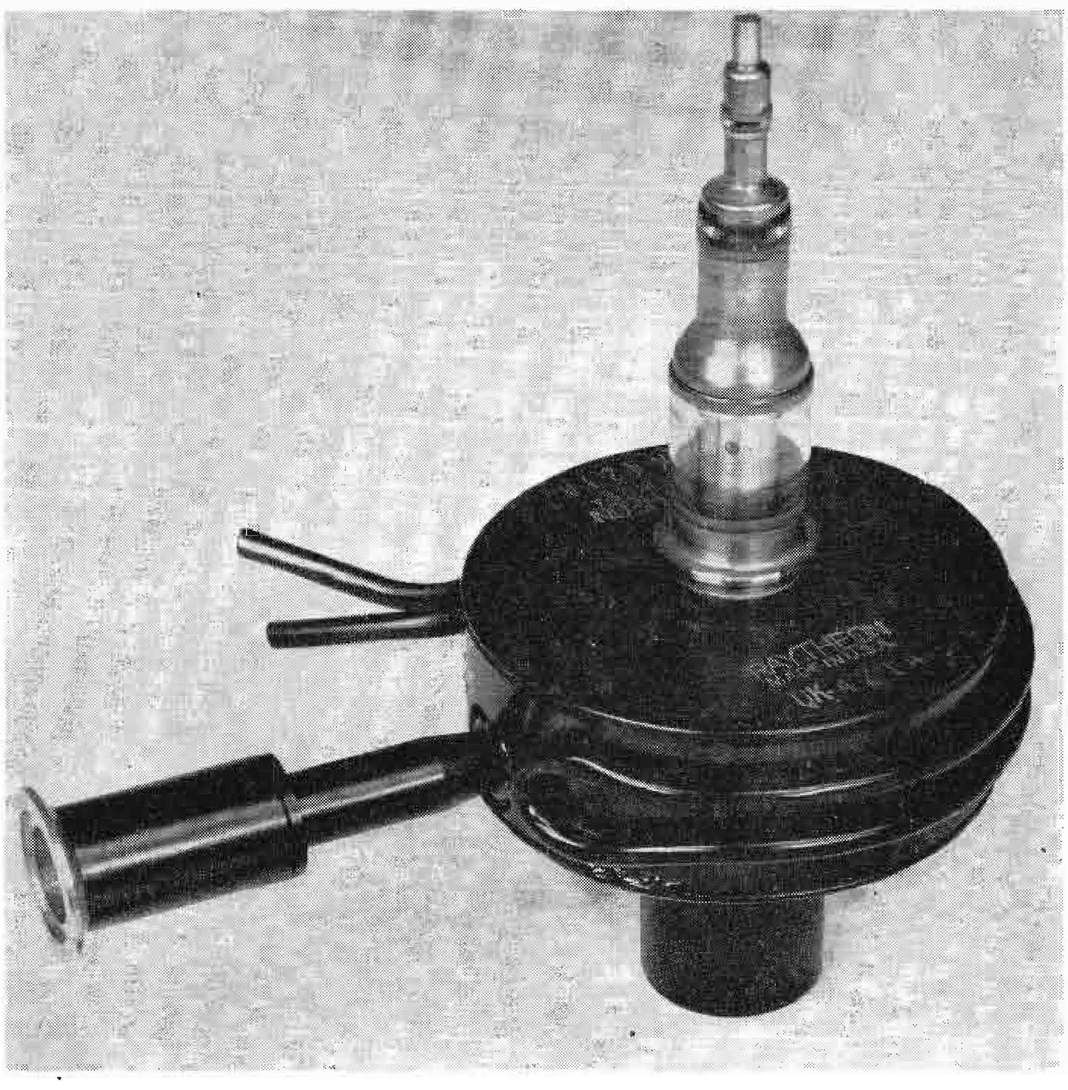


Fig. 2: Wave functions in reverse wave oscillators

Fig. 3: External view of experimental M-type oscillator tube for 2000-3000 MC



Wave Microwave Oscillator

Pioneer tube development has power output of 200 watts at 30% efficiency. Features include electronic tuning from 1624 to 2740 MC by variation of the anode voltage

"These lines possess the general properties of electric filters, characterized by frequency bands ε over which the line is capable of transmitting energy. Assuming a lossless line, in the pass band, ψ is a real quantity. The variation of ψ with frequency is the dispersion characteristic of the line. The velocity of propagation of energy along the line is:

$$\nu_g = p\,(d\,\omega / d\,\psi) \qquad (2)$$

"The fields along the line satisfy the condition:

$$E\,(x, y, z + np) = E\,(x, y, z)\, e^{-jn\psi} \qquad (3)$$

"One may write:

$$E\,(x, y, z) = \sum_{k=-\infty}^{+\infty} e_k\,(x, y)\, e^{-j\frac{z}{p}(\psi + 2k\pi)} \qquad (4)$$

$$e_k\,(x\,y) = \frac{1}{p}\int_0^p E\,(x, y, z)\, e^{j\frac{z}{p}(\psi + 2k\pi)}\, dz \qquad (5)$$

This paper
was presented at the
1953 National Electronics Conference
Sept. 28-30, Chicago, Ill.

"In this form the field along the line appears as if it were a superposition of traveling waves having phase velocities:

$$\nu_k = \omega p / (\psi + 2k\pi) \qquad (6)$$

"These 'waves' do not exist separately since each corresponding field does not satisfy the boundary conditions at the surface of the line. When ν_K has a positive value in the preceding equation, i.e. (if $O < \psi < 2\pi$) for $K \geqq O$, the phase velocity is in the same direction as the energy velocity; the corresponding waves will be called 'direct waves.'

"When ν_K has a negative value ($K < O$), the phase velocity is in a direction opposite to the energy velocity, and the corresponding wave will be called a 'reverse wave.' The phase velocities of these waves play an important part in the interaction between an electron beam and the electric field of a line having a periodic structure. It is therefore convenient to represent graphically the properties of a delay line, not by the variation of ψ with frequency, but

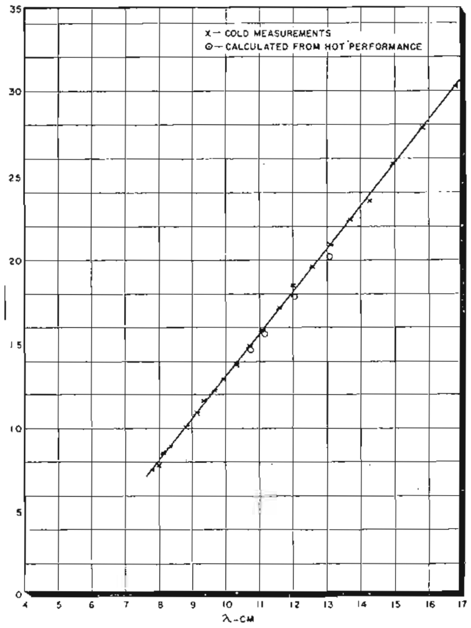


Fig. 5: Dispersion characteristics of the delay line of experimental oscillator tube

by the variation of the 'delay ratio' $c/|\nu_k|$ with the wavelength λ.

"In the graph of Fig. 1, lines of constant ψ are straight lines passing through the origin with a slope $\psi/2\pi p$. Curves corresponding to various values of k are derived, one from the other, by a simple construction (ab=bc=de=ef). Tangents to points of these various curves, corresponding to a given value of λ, cut the c/ν axis at a point, the ordinate of which is c/ν_g for direct waves and $-c/\nu_g$ for reverse waves; the largest value that ν_g can assume is C, demonstrating that Δ, the dispersion, defined as the variation of the delay ratio with wavelength

$$[\Delta = d(c/|\nu_k|)/(d\lambda/\lambda)]$$

can be positive, negative, or zero for direct waves, with its maximum positive value equal to

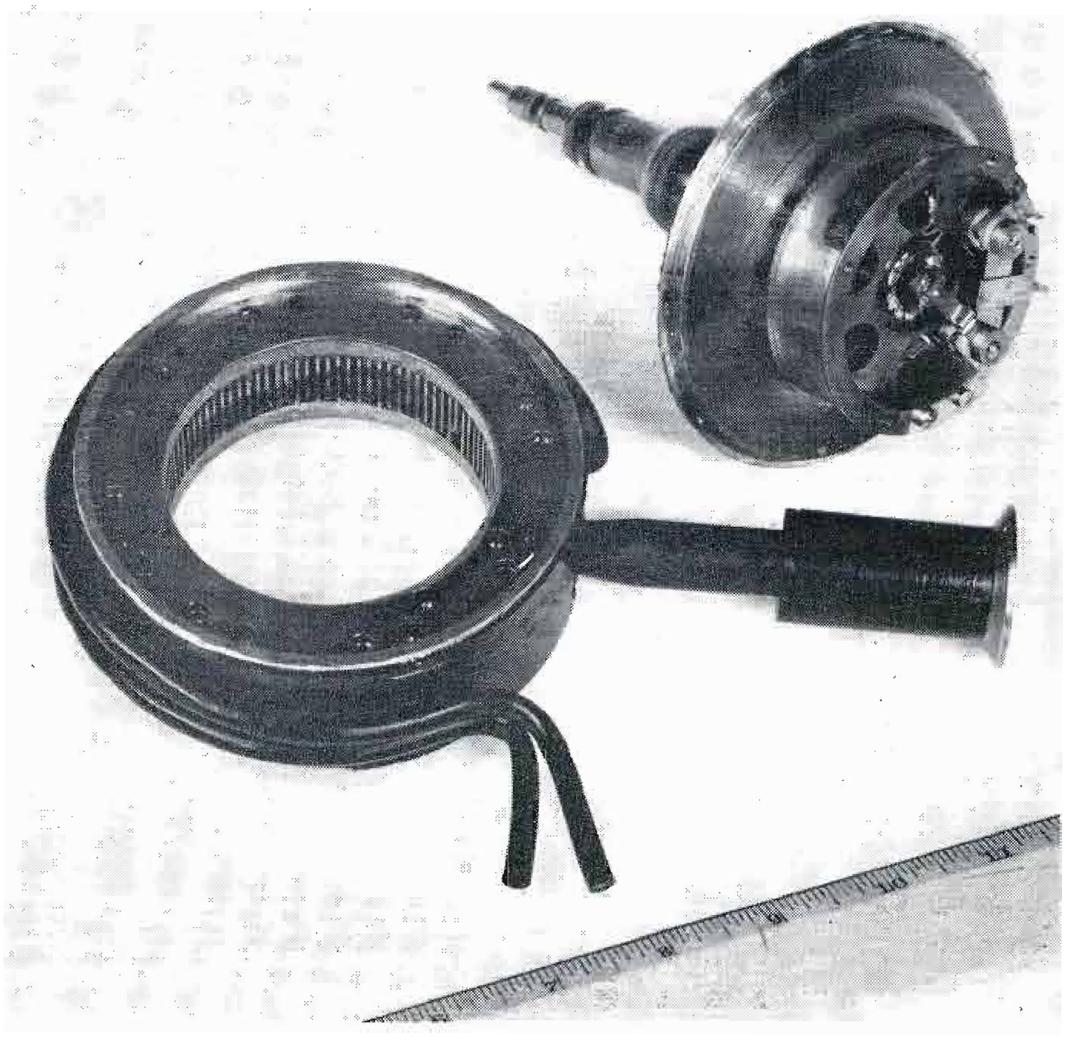
$$c/|\nu_k| - 1.$$

For reverse waves, the dispersion is necessarily positive and its minimum value is equal to

$$c/|\nu_k| + 1.$$

It is readily seen that the form of

Fig. 4: Internal view of experimental oscillator tube



the dispersion curve can be adapted for its particular use in a microwave tube by a suitable choice for the line structure."

Guenard's Summary

Backward wave oscillations can be produced by providing an electron beam traveling at substantially the velocity of a reverse wave, and adapted to couple energy to a periodic delay line. A suitable summary of this phenomenon has also been given by Guénard et al[8] as follows:

"About a line having a periodic structure with pitch p, excited by electromagnetic waves, there appears a field having a periodic spatial distribution; the fields of adjacent cells of the line having the same spatial distribution with a phase difference ψ. If, along this line, one injects an electron beam with velocity v_e, there is an interaction between the beam and the line when the velocity of the electrons is such that they encounter the fields of successive cells in the same phase, or substantially in the same phase. This condition can be written in a general manner as

$$\omega_p/v_e = \psi + 2k\pi \ (k = 0, \pm 1, \pm 2, \ldots) \tag{7}$$

by assigning a positive value to v_e for electrons moving in the same direction as the energy in the line, and a negative value in the opposite case. The foregoing condition means that the electron velocity coincides with the phase velocity of one of the 'direct' or 'reverse' waves which propagate simultaneously in the line. These two cases lead to two types of tubes with different properties. This can be understood by visualizing that the coupling between the beam and the line is obtained by means of gaps; the action of the field of these gaps causes the formation of bunches of electrons in the beam. When these bunches pass across a gap, they excite two waves, O_1 and O_2 in the line, the energy of which propagates away from the gap, and the action of the beam F on the line L is manifested by the superposition of waves which the beam excites across successive gaps. When the beam velocity equals the velocity of a 'direct' wave, the waves O_1 excited in the different gaps (the energy of which propagates in the direction of the beam) have the same phase, and their effects are additive. Waves O_2 have different phases and almost completely cancel themselves. See Fig. 2a. Energy carried by the line increases in the direction of electron motion and the tube can be used as an amplifier. Traveling wave amplifier tubes are based on this principle.

Beam Velocity

"When the beam velocity is equal to that of a 'reverse' wave, waves O_2 (the energy of which propagates in a direction opposite to that of the beam) have the same phase, and their effects are additive as in Fig. 2b. Therefore the amplitude of the field carried by the line increases toward the origin of the beam, and energy created by the action of the electron beam travels in a direction opposite to it. This interaction is the principle of the new oscillator tubes. The frequency of oscillation of these tubes is determined by the fact that the electron velocity must be close to that of a 'reverse' wave. It therefore varies with electron velocity according to the dispersion curve of the line used.

"This principle has been applied in two ways, as shown schematically in Figs. 2c and 2d, which we have named Carcinotrons, Type O and M

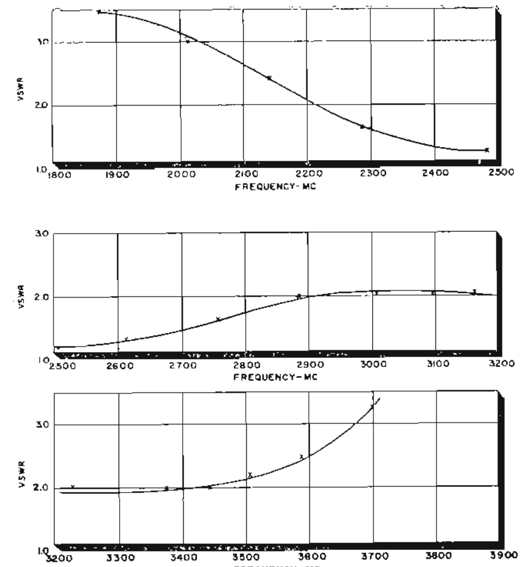


Fig. 6: Impedance match between coaxial output line and equivalent linear delay line

respectively. In the Type O Carcinotron, the beam travels near the line in a space at potential V. The velocity of the electrons thus being $\sqrt{2e\,v/m}$. which together with the dispersion characteristics of the line, fixes the law of variation of frequency with voltage. Calculations give, in this case, the current for starting of oscillations as

$$I_s = \pi^3 \frac{V}{Rl^3}\frac{\nu_0}{\omega} \tag{8}$$

where R is the coupling resistance of the beam, l the length of the line.

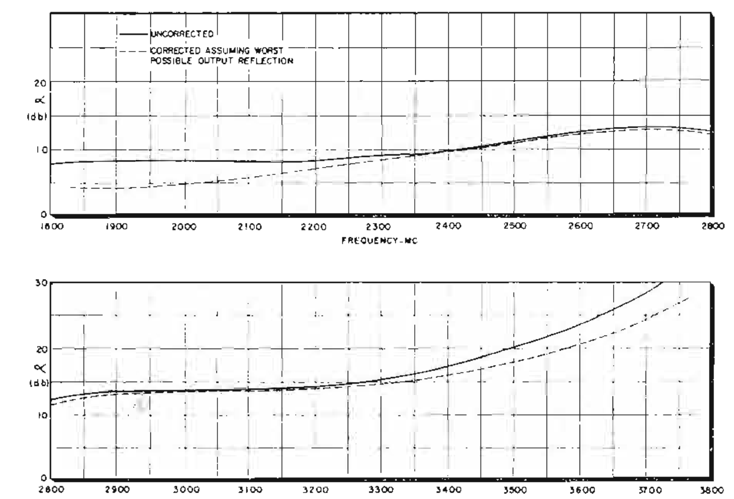
"In the M Carcinotron, the beam moves in crossed electric and magnetic field V/d and B respectively. The average translational velocity of the electrons is then $v_e = V/dB$ and the oscillation frequency depends on both the electric and magnetic fields. Calculation of the current for starting of oscillations gives:

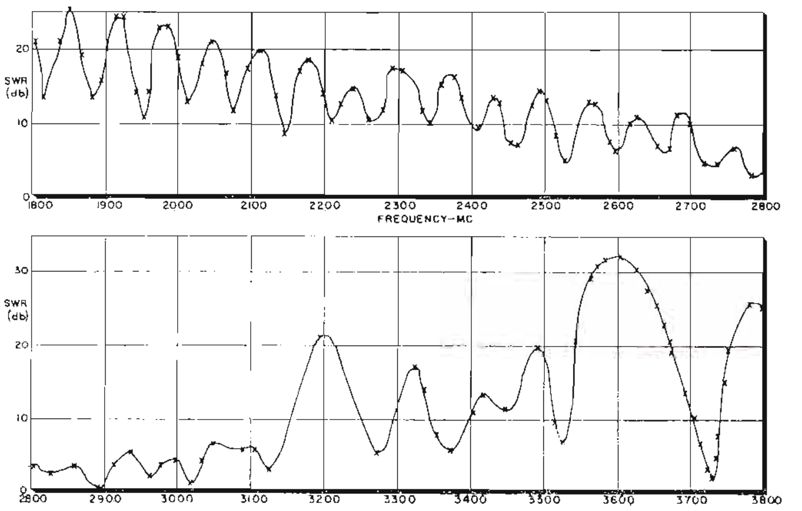
$$Ia = \frac{\pi}{2}\frac{V}{Rl^2}\tanh\left(\frac{\omega}{\nu_e}x_o\right)\Big/\frac{\omega}{\nu_e}d \tag{9}$$

"Space charge effects modify this critical starting current, increasing it in the O type and decreasing it in the M type tubes. In both cases en-

(*Continued on page* 157)

Fig. 7: (l) Attenuation introduced at collector end of equivalent linear delay line. Fig. 8: (r) SWR presented by the completed oscillator tube





Transistor Transient Response

Physical considerations in high-frequency and transient analysis show how equivalent circuits may be utilized to maximum within limitations of initial assumptions

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THE fundamental physical properties of transistors are generally thought to be well understood at this time, although much is still to be desired in the application of these fundamentals to circuit theory. Many of the equivalent circuits for transistors, which have appeared in the literature to date, are based upon implicit assumptions of such a nature as to restrict the usefulness of the circuit. This is especially true for high-frequency and transient analysis.

Junction Transistor

The ensuing discussion will be limited to junction transistors. Insofar as point-contact types approximate the behavior of junction transistors, the analysis will also apply. However, since little is known about those surface effects which may considerably affect the behavior of point-contact transistors, analogy between the two types should be made with caution.

Fig. 1 represents a schematic drawing of an n-p-n- junction transistor, biased in its normal manner. The boundaries between the N and P regions form semiconductor junctions which may be represented by diodes. The forward direction of the p-n "diode" is in a direction from the p to the n region. Thus, the emitter-base junction is biased in the forward direction of easy current flow and the collector-base barrier is biased in the reverse direction. In the N-region of the transistor, there is an excess of electrons which are loosely bound to their parent atoms; the loosely-bound electrons are supplied by donor "impurity" atoms of elements occupying the 5th group of the periodic table.

Since the intrinsic semiconductor material (germanium, for example) is in the 4th group of the periodic table, one electron per impurity atom is free to move. Conversely, the impurity atoms in the P-region of the transistor are from the 3rd group of the periodic table, and since the impurity atoms in the P-region cannot supply enough electrons to fill the bonds of the intrinsic material, "holes" are formed. A hole is a region where an electron may be trapped. An electron which moves into a hole may leave a hole behind it, and so hole movement may be treated as positive currents. Electron and hole dynamics in semi-conductor materials are predictable by quantum mechanical concepts.[1] In limiting cases, quantum mechanics may be applied as a statistical tool.

Energy Distribution

Instead of thinking of electrons in N-type material as "loosely bound," it is more significant to think of them as having higher probabilities of jumping from a bound atomic state to a conducting state. Thus, N-type and P-type material may be considered relative to the electron energy distribution associated with each. Figs. 2a and 2b illustrate the electron energy distribution for N- and P-type semiconductors respectively. An electron in the valence band is "tightly-bound" to its parent nucleus.

In the conduction band, electrons have absorbed enough energy to be

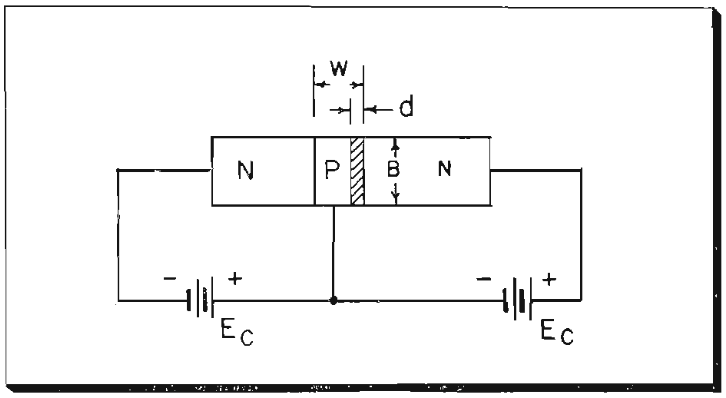
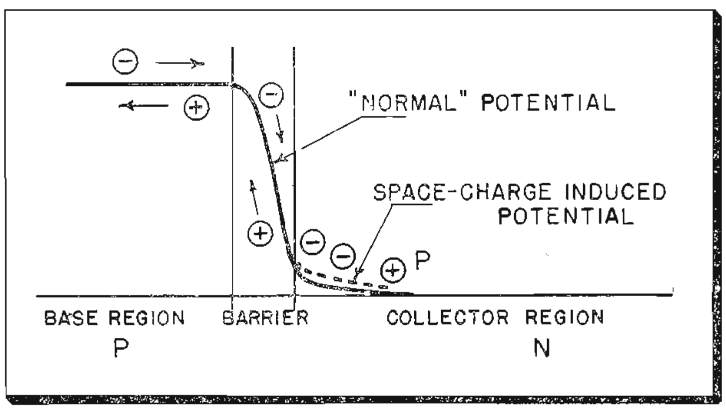
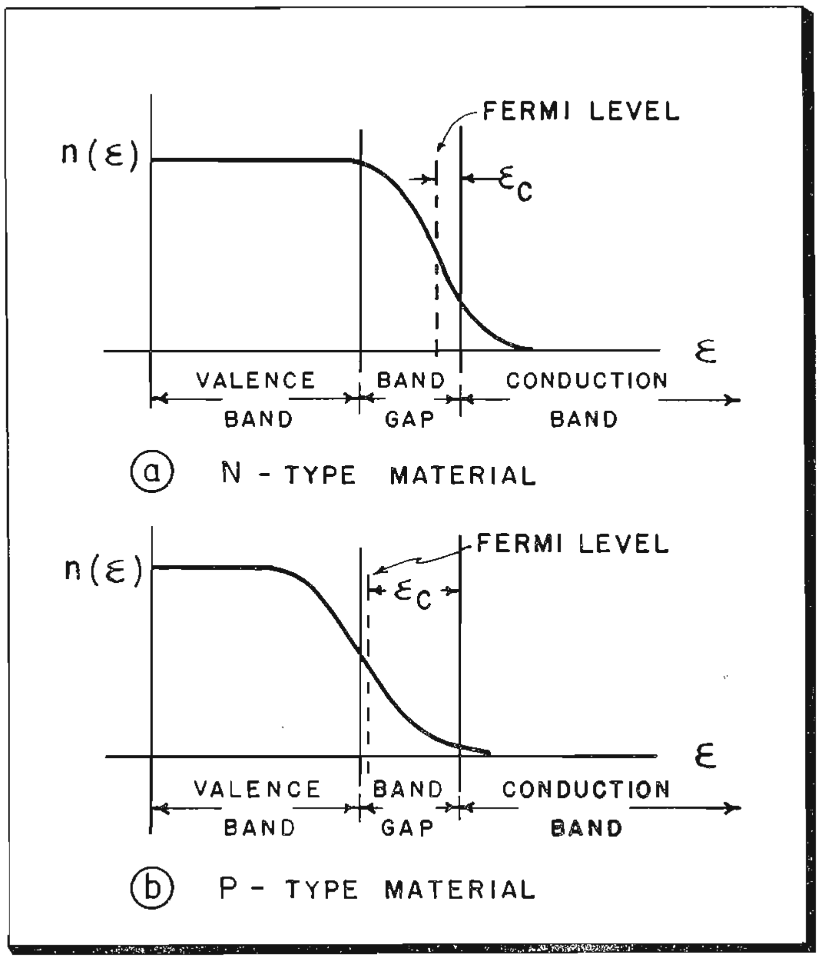


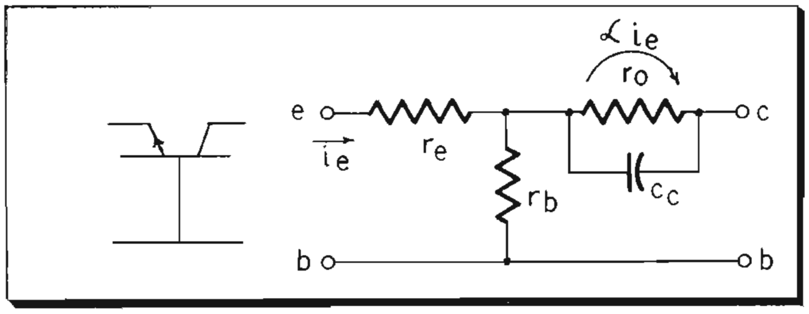
Fig. 1: Schematic representation of a junction transistor

Fig. 2: (r) Electron energy distribution in N and P materials

Fig. 3: Current multiplication effect at the collector







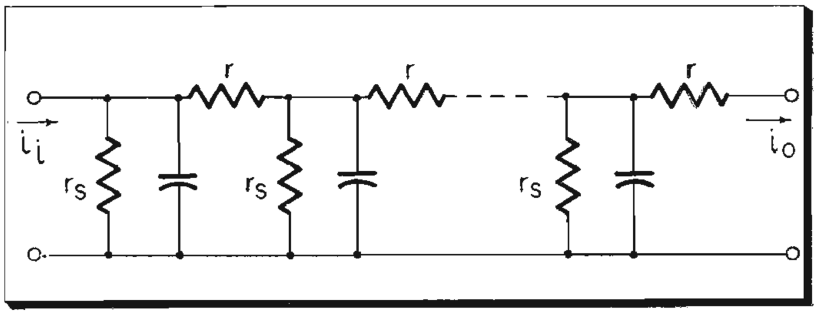


Fig. 4: (l) Transistor low frequency equivalent circuit. Fig. 5: (r) Transmission line representation of diffusion process

"free" of the electric field of the atomic nucleus. Between the conduction band and the valence band is the band gap, which represents the minimum amount of energy an electron must have in order to free it from its bound atomic state. The electron energy distribution, which represents a statistical average of individual electron energies, in the N-region of a transistor is such as to increase the probability of electrons falling into the conduction band.

In the P-region of a transistor, the electron energy distribution is such as to increase the probability of electrons falling into the valence band. The electron energy corresponding to a 50-50 chance of an electron falling into either the valence band or the conduction band is known as the Fermi level. It is apparent that the Fermi level will be close to or in the conduction band for N-type material (where the Fermi level relates to *electron* energies), and that the Fermi level will be in close proximity to the valence band for P-type material.

Free Electrons

A significant point in this discussion is that both N- and P-type semiconducting materials contain free electrons, and that in both type materials it is possible, by application of energy E_c (see Fig. 2), to raise electrons from the valence state to the conducting state. Since E_c may be supplied by photons, cosmic rays, thermal effects, etc., electrons are always in the process of being "liberated" or "captured" in a transistor, even when no external electric energy is applied. The concentration densities of electrons and holes, when no external electric energy is supplied, are referred to as the thermal equilibrium values.

The boundary between a p and n region forms a contact potential.[2] Although charges will continuously flow across the semiconductor boundaries, the net rate of flow of charges is zero, since no external current paths are provided. The boundary itself consists of ionized atoms which are firmly bound in an atomic lattice structure. When a p-n boundary is electrically biased in its forward direction, electrons are supplied to the positively charged ions in the n-region and withdrawn from the negatively charged ions in the p-region, thus tending to reduce the contact potential and making it easy to pass current across the boundary. But when the boundary is biased in its reverse direction, electrons must be supplied from neutral atoms in the N-region and to neutral atoms in the p-region.

Ionized Atoms

The net result of the inverse bias is to increase the number of ionized atoms and to increase the contact potential across the boundary. An increase in the number of ionized atoms at the boundary of a p-n junction causes an increase in the boundary "thickness."

Thus, for the transistor shown in Fig. 1, the effective base width is (W-d) where the barrier thickness, d, is a function of the collector voltage, E_c. The dependence of base width on collector voltage is sometimes referred to as the "Early effect."[3] When very small barrier (contact) potentials exist, the layer of ionized atoms along the boundary is very thin and, consequently, the barrier thickness can often be neglected. It is for this reason that the boundary between the emitter and base is generally assumed to have zero thickness.

When a signal is applied to the emitter of an n-p-n transistor which is biased as illustrated in Fig. 1, electrons are injected from the emitter into the base region. (For a p-n-p transistor, holes would be injected from the emitter into the base.) At the same time, holes are injected from the base into the emitter. (For a p-n-p transistor, electrons would be injected into the emitter.) Electrons in the base of an n-p-n transistor will move to both the collector boundary layer and the base ohmic contact by virtue of electric field and concentration (density) gradients.

When these minority carriers (electrons for the n-p-n transistor and holes for the p-n-p transistor) arrive at the collector barrier, they experience a sudden and large increase in potential energy, supplied by the collector voltage, and consequently are immediately swept into the collector region. The concentration of carriers in the base at the emitter-base boundary is high, but the carrier concentration at the collector barrier is very nearly zero. Because of the energy increase which a carrier experiences in traveling from the emitter to the collector, a transistor has the properties of a power-gain device.

When moving through the base region of an n-p-n transistor, electrons may "fall" into valence bands of ionized atoms and may remain bound for relatively long periods of time. The process of electron "capture" by holes is referred to as "recombination." Barring all other factors, the current amplification of a transistor would be less than unity because of recombination. Recombination is often measured by the mean free lifetime of minority carriers in a p or n region.

However, space charge due to electrons in the potential field in the collector can modify the potential distribution as shown by the dotted line. The hole, p, will then experience a potential gradient which drives it toward the base. If this hole can get through the electron accumulation without recombining, it will add to the collector current.

From the above discussion it may be readily appreciated that the current transfer mechanism in transistors is not a simple matter. If we can assume that the known transistor phenomena, described above, will enter into the current transfer expression as multiplication factors, the ratio of collector current to emitter current, or α, can be written as:

$$\alpha = \frac{i_c}{i_e} = \gamma \cdot \beta \cdot \alpha \qquad (1)$$

γ, known as the injection ratio, results from the fact that a signal applied to the emitter will cause minority carriers to be injected into both the base and emitter regions. γ is the ratio of current carried by minority carriers in the base to the total current which crosses the emitter barrier. Eq. 2 defines γ for an n-p-n transistor, where I_{e_B} is the emitter current carried by electrons in the base and I_{e_e} is the emitter current carried by holes in the emitter.

$$\gamma = \frac{I_{e_B}}{I_{eB} + I_{e_e}} = \frac{1}{1 + I_{e_e}/I_{e_B}} \qquad (2a)$$

As illustrated in Fig. 3, the high electric potential which occurs across the base-collector barrier for an n-p-n transistor is the basic collecting mechanism in the transistor. However, under certain conditions,[4] the accumulated space charge created by electrons which have just crossed into the collector can draw holes from the collector region into the base, the net result being a current multiplication at the collector. Fig. 3 illustrates this effect by showing a hole, p, which under ordinary circumstances experiences no potential gradient in the collector. γ is a function of frequency, operating point and transistor construction.[2]

Transport Factor

β in Eq. 1 is a transport factor, and represents the phenomena involved when carriers in the base region cross from the emitter to the collector. β is a function of frequency, operating point, transistor construction, electric field distribution in the base and carrier density distribution at the emitter boundary.

β may be defiined by the current transfer ratio in the base:

$$\beta = I_{c_B}/I_{e_B} \qquad (2b)$$

where, for the n-p-n junction transistor of Fig. 1, I_{cB} is the collector current due to electrons crossing the collector boundary and I_{eB} is as defined for Eq. 2a.

α* is due to current multiplication at the collector; it is also a function of frequency, operating point and transistor construction. α* may be defined by:

$$\alpha^* = (I_{c_e} + I_{c_B})/I_{ce}$$

where I_{c_e} is the collector current carried by electrons in the collector and I_{c_B} is the collector current carried by holes in the base (for the n-p-n transistor).

The problem of the circuit engineer who wishes to devise an equivalent circuit for the transistor is one of taking into account the complex physical relations which are fundamental to transistor mechanics. Obviously, simplifications will have to be made if a useful circuit is to be developed. But it is of fundamental importance to the applications engineer that he understand not only the equivalent transistor circuit but also the implicit assumptions inherent in the circuit.

Transistor Equivalent Circuit

To the applications engineer, a transistor represents a four-terminal black box to which must be assigned an input impedance, an output impedance, transfer functions, etc. The dc equivalent circuit, the low-frequency equivalent circuit, the high-frequency equivalent circuit and the transient-equivalent circuit will each be different because of the assumed simplifications and will, in the order stated, be increasingly complex. The equivalent circuit itself must have parameters, and it is desirable that these parameters correspond in some way to the physics of the transistor. This paper will not be concerned with the derivation of equivalent circuits,[1,4] other than to point out the problems involved in deriving a satisfactory circuit. However, examining the equivalent circuits which are currently in use can lead to an understanding of the fundamental assumptions which had to be made.

Consider the basic T- equivalent circuit of Fig. 4, which represents a transistor at low frequencies. Here, the impedance of the emitter-base barrier has been represented as a constant resistance, r_e; since this barrier is biased in its forward conducting direction, r_e may be expected to be of small value. The collector-base barrier is represented by r_c and C_c; since the collector barrier is biased in its inverse conducting direction r_c may be expected to be of high value. C_c represents the collector barrier capacitance, and is due to the physical storing of charge between the base and collector. The value of C_c depends upon the geometry of the barrier in addition to the operating point of the circuit. Ideally, the collector is isolated from the emitter by virtue of the high resistance, r_c, and so the current flowing out of the collector can be represented by a current generator, αi_e.[4] A fourth parameter is needed, and so a base resistance, r_b, is added to the circuit. Ideally, r_b represents the physical resistance between the emitter barrier and the lead which connects to the base region.

Physical Considerations

What does the circuit of Fig. 4 neglect in the way of physical considerations? First of all, the injection ratio, γ, is assumed to be unity. Second, the current multiplication factor, α*, is assumed to be unity. Both these conditions state that signal (ac) carrier current flows *only into* the base at the emitter junction and *only out* of the base at the collector junction. (For γ to be unity implies that I_{ee} in Eq. 2 is zero.) Third, the equivalent circuit of Fig. 4 represents r_e, r_b, r_c and C_c as independent of the circuit voltages and currents. This implies that the dc biasing current maintains the circuit parameters constant despite the superimposed ac signal, which, in turn, means that the equivalent circuit is good only for small signals. Fourth, and perhaps most significant, the circuit of Fig. 4 neglects the transport phenomena (β in Eq 1.) in the base of the transistor, taking into cognizance only the fact that the magnitude of i_c will be related to the magnitude of i_e by some amplification factor, α.

Experiment has shown that the circuit of Fig. 4 is adequate to represent transistors at low frequencies, for small signal magnitudes. How-

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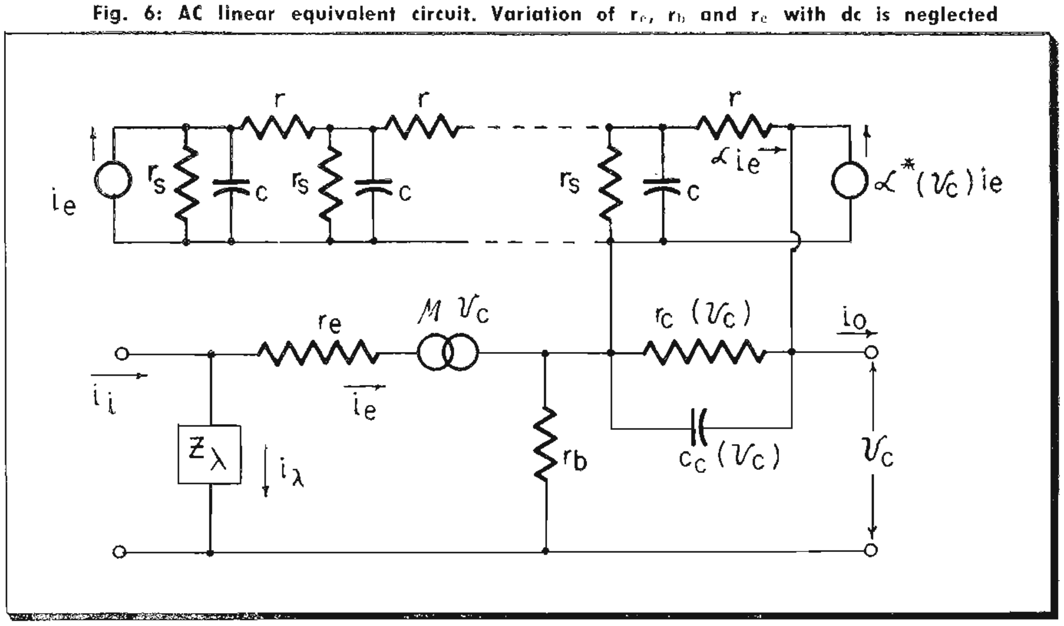
Fig. 6: AC linear equivalent circuit. Variation of r_e, r_b and r_c with dc is neglected



Project "Tinkertoy"—Step Toward

Fig. 1: Modules comprise stack of wafers upon which components are mounted

By DR. ALBERT F. MURRAY
Consulting Editor
TELE-TECH & ELECTRONIC INDUSTRIES

THE day of the automatic factory for radio, TV and electronic equipment is approaching. A trip through the pilot factory in Arlington, Va., which is based on National Bureau of Standards' developments, gives a preview of what to expect in the not-too-distant future. It will be found that printed circuits are the key to mechanized electronic production.

The NBS project "Tinkertoy," carried out for the Navy Bureau of Aeronautics has taken three years and over $4.7 million to develop to a point where a pilot factory is turning out automatically the electronic portion of sonobuoys for the Navy. Dr. Astin, director of NBS, said the credit in his organization goes to J. G. Reid, Jr. for overall supervision and to Robert L. Henry, Project Leader. Mr. Henry is shown in Fig. 7 with one of the amazing automatic testers for complete units. Other contractors on this project will be mentioned later.

To successfully produce devices automatically, two developments having a hand-in-glove relationship had to be achieved. These were the design of an automatic fabrication system, and the formulation of an equipment design method for electronic circuits capable of being automatically produced. We will take up the latter first.

Design Pattern

It was decided to employ ceramic wafers, 7/8 in. square by 1/16 in. thick, as bases for the mounting of automatically fabricated capacitors and resistors as well as other components. Printed circuits on the wafers connect the components to the desired notches, three on each side, which are also silvered prior to coating with solder. Four to six wafers are stacked and held by wires soldered in the notches to form a unit which is usually associated with an electronic stage and topped by a socket for vacuum tube. No mention was made in the September disclosure of Project Tinkertoy of the future use of transistors instead of vacuum tubes, but there appears no reason why transistors will not fit in with this pattern of design. A number of these individual subassemblies, shown in Fig. 1, called by the NBS "modules," or building blocks, can be combined to form a major assembly. Six such modules can be assembled into a six-tube radio receiver.

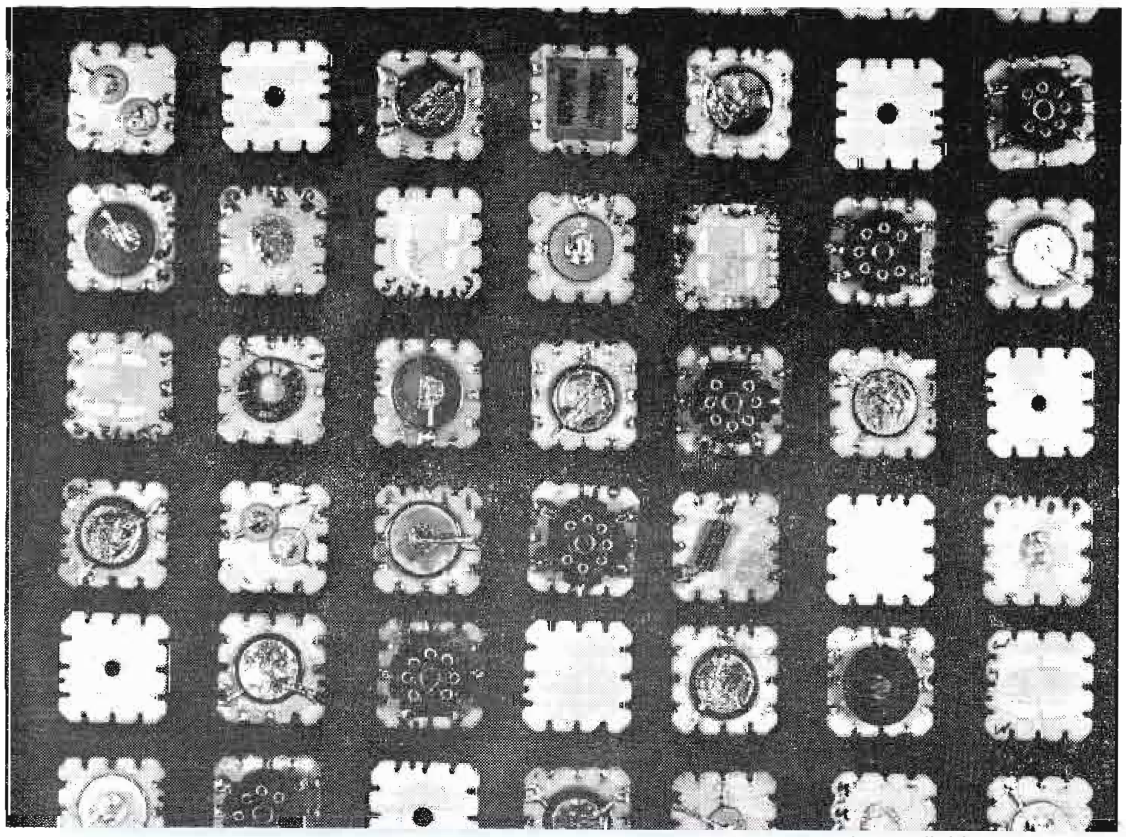
Now we have seen what the design engineer has to work with. Two capacitors and up to four resistors can be assembled on each wafer. The engineer need have no concern about his finished product meeting military environmental requirements because this type of rugged construction has passed all these tests. He can expect performance generally equal to that from conventional assemblies. The pattern best fits circuits composed of R and C, also those having small values of L so that the inductors can be of the spiral, printed type. Of course toroids, potentiometers, crystal diodes, etc. can be used, as shown in Fig. 2, but probably not handled automatically at present.

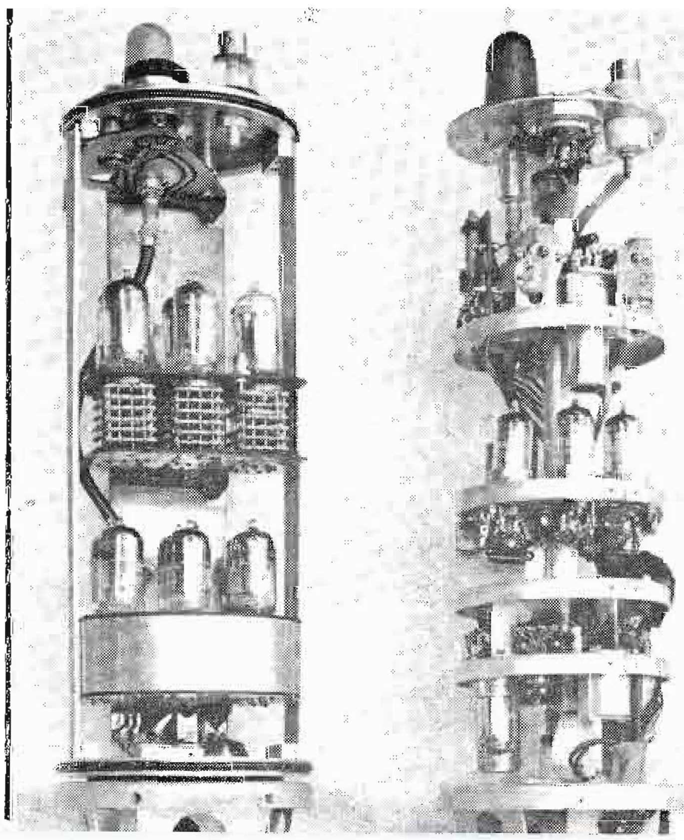
The result of applying this design to a sonobuoy, Fig. 3, to an expendable drone radio control receiver and to a radio altimeter, Fig. 4, results in some, but not a great deal, average reduction in both weight and space.

Automatic Fabrication

Production-minded readers will want to know the "how" of this pilot plant which can produce 1,000 "modules," about 5,000 wafers, per hour. A layout of the plant is shown in Fig. 5. From raw materials the fac-

Fig. 2: (l) Arrangement of various types of parts-mounted wafers. Parts include printed conducting circuits, tape resistors, titanate capacitors and tube sockets. Fig. 3: (r) Conventional submarine detection device at right is compared to equivalent device made by Project Tinkertoy process





the Automatic Factory

Radically new mechanized method of producing components for electronic equipment developed by NBS. Basic product is rugged printed circuit on ceramic wafer. Punched cards control 100% inspection system

tory turns out wafers, ceramic capacitors and adhesive resistors. These are the basic, large-quantity parts fed into the production line. The fabrication process, as detailed by NBS, is passed on to the reader in condensed form because of space limitations. For a full description of the technical aspects it is suggested that information be obtained from Mr. Hugh Odishaw, Asst. to the Director, National Bureau of Standards, Wash. 25, D.C.

WAFERS: These are composed of a combination of talc, kaolin and barium carbonate which is mixed, filtered, dried and refined into a flour mixture that is fed into a pilling machine which stamps out the wafers. The wafers are fired in a tunnel kiln at 2300° for nine hours. Next, they are mechanically gauged for size and made ready for Metalizing.

CAPACITORS: The dielectric is magnesium, barium, calcium and strontium titanate made in the same manner as the wafers, but measuring ½ in. sq. by 2/100 in. thick. Values from 7 μμf to 0.01μf can be produced with less than 20% rejects.

RESISTORS: The formula comprises a mixture of carbon or graphite, resin and a binder, all ground into a fine powder. This is sprayed on a moving loop of heat-resistant asbestos paper tape, known as "Quinterra," to which is applied a cover of polyethylene tape. The finished tape is stored under refrigeration. A 75-foot roll will give a yield of 10,000 resistors. Values range from 10 ohms to 10 megohms, power dissipation ¼ watt, change in resistance value at temperatures up to 400° F is found not more than ±10%.

METALIZING: This term relates to the application of silver paint (a DuPont product) to form circuit conductors on the wafer and/or on the capacitor body and also to the curing that follows. Circuits are painted automatically by pressing with rubber squeegees the silver paint through stencils cut to the desired form from 160-mesh stainless steel screens. After painting, the ceramic part slowly travels through the curing furnace. The 12 notches in the edge of the wafer are also metalized so that a later dip-solder operation (which unfortunately has to be done twice to build up enough solder in the notch), can prepare the wafer to receive the wire busbar connections. After firing, the silver is so imbedded in the ceramic that the author found it impossible to remove it even with a knife blade. Fig. 8 shows the wafer pattern printer, and Fig. 9 the vibratory feeder.

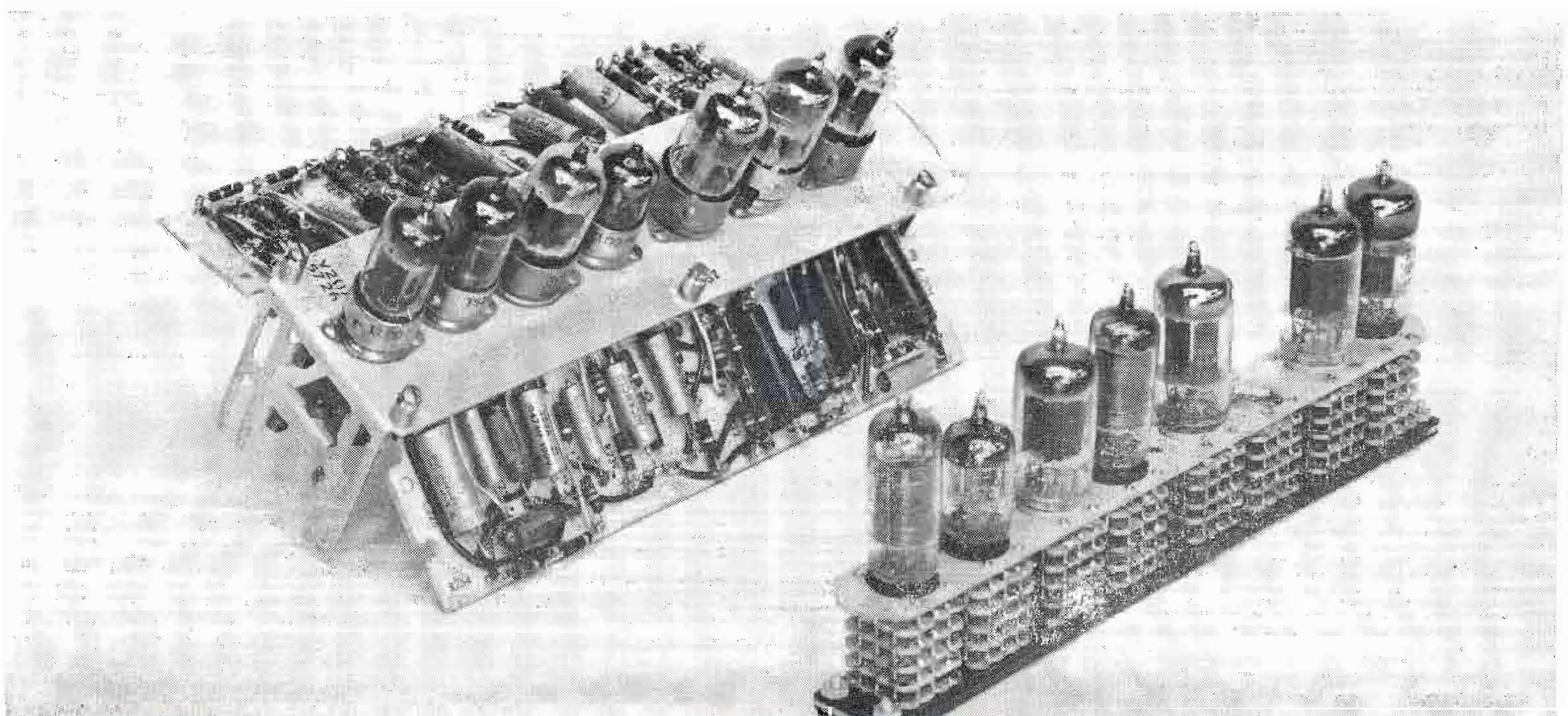
ASSEMBLY OF COMPONENTS: Entirely automatically two capacitors per wafer can be attached. See Fig. 6. A well-designed tape resistor attaching machine, holding rolls of resistor tape, grasps the passing wafer, cuts the tape into ½ in. lengths, presses the resistor against the printed electrodes, applies pressure, then passes the unit on to the next operation. Tube sockets are mounted on wafers by means of rivets so that the terminals are aligned with the proper busbars. It was observed that the riveting process cracked some of the wafers, yet attempts to break a wafer in the hand showed they had outstanding strength.

Unit (or Module) Assembly

A single machine assembles up to six wafers in the following manner: Vibratory feeders, containing the correct wafers for the unit, cause the wafers to progress to a loading device where, after they are properly stacked, six riser wires are soldered in the notches on opposite sides of the wafer. The assembly, illustrated in Fig. 1, is then turned 90° and six wires are soldered to the other sides. There follows an electrical test. Another automatic machine then clips the desired riser wires so that all of the circuits function correctly.

ASSEMBLY OF UNITS INTO COMPLETED DEVICE: No automatic equipment for this was provided. Normally, the required number of units are mounted by hand on a copper-clad base. By etching,

Fig. 4: A design engineering application by Sanders Associates of the National Bureau of Standards' Project Tinkertoy technique is the compact radio altimeter shown at the lower right. This may be compared with the conventional radio altimeter at left, which uses standard components and fabrication



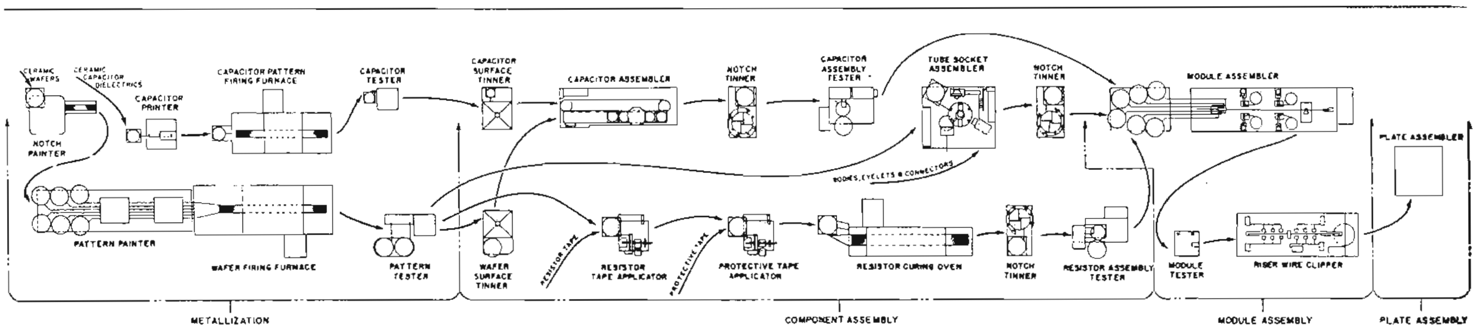


Fig. 5: Schematic diagram of Project Tinkertoy mechanized assembly line shows sequence of machine operations for producing components

circuits have been formed on the base to connect with the riser wires of the units by means of dip-soldering.

The writer was tremendously impressed with the automatic testing system that had been worked out by NBS. Much of this was supplied by Communication Measurements Lab., Inc., Plainfield, N.J. Each stage of production is followed by an automatic device that gives 100% inspection. Electrical portions are compared with their standard equivalents by means of electronic computers, bridge circuits and the like. In Fig. 7 is seen one of these devices testing the finished unit. The unit under test slides into position and lingers there only long enough for its performance to be compared with that of a standard unit (in the cylinderical can on the left). The good units fall in one of the metal boxes under Mr. Henry's hand, the rejects drop in the other box. In the case of a reject, one or more of its faults are indicated by the flashing of one or more of the tell-tale signal lamps located on the black bakelite panel.

Testing Wafers

The other testing machines, similar in appearance, test wafers in the manner specified by a Code Card, a punched card, prepared by the design engineer. These cards, measuring about 4 x 8 in., when not in use in a testing machine are attached to the metal boxes in which the assemblies are carried from machine to machine. Unskilled operators can place the punched card in the testing robot, thus causing the proper testing circuits to be energized so that the parts are quickly tested. Next, the inspected units (and the rejects) in their containers, with the punched code card attached, can be removed leaving the testing machine available for instantaneous shift to the task of testing an entirely different wafer carrying a different circuit.

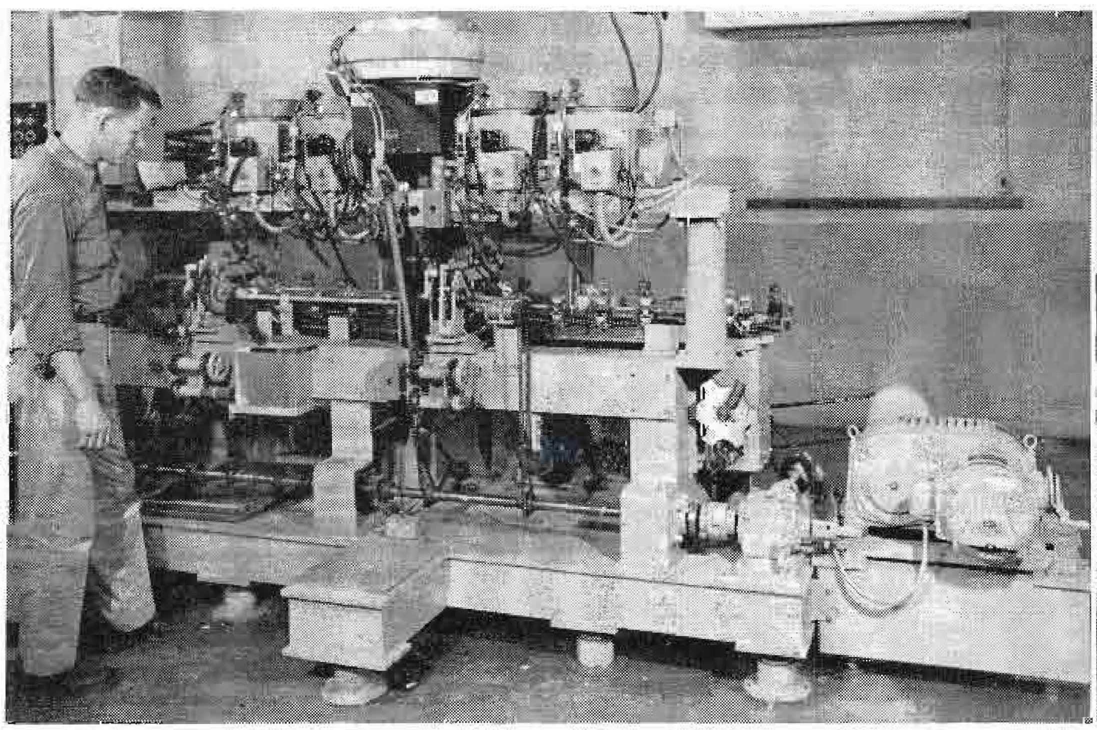
This completes the description of typical processes in this automatic plant, an overall view of which is given in Fig. 10. Some of the special machines were built by the Doughnut Corp. of America. The major design and construction of the automatic equipment was done by the Kaiser Electronics Div. of Willys Motor Co. This company, under contract with Bureau of Aeronautics, is operating the plant at present. Sanders Associates, Inc., of Nashua, N.H., electronic consultants, worked out major applications and did environmental studies.

The advantages are:

1. Rapid conversion from military to civilian production and vice versa as well as the ability to switch production from one type of equipment to another type. A change of printed circuit stencil takes only a few minutes. It was said that a change in the type of equipment produced could be made every two hours if this was

(*Continued on page* 132)

Fig. 6: (l) Machine automatically orients, assembles and bonds one or two titanate capacitors to ceramic wafers. Fig. 7: (r) Completed modules are inspected with the aid of a punched card system which programs a check of each circuit and component on the wafers against a standard



CBS' New Color-TV Tube

Employing curved-mask to overcome convergence effects, and photoengraving techniques for depositing color phosphors directly on faceplate, design is highly adaptable for mass production.

By BERNARD F. OSBAHR
Executive Editor

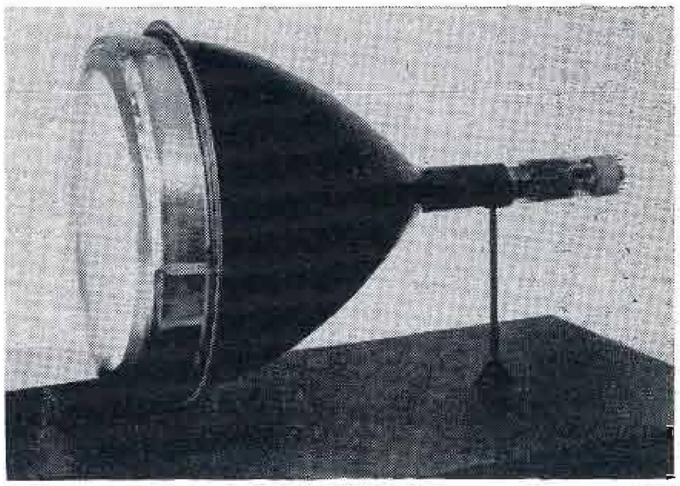


Fig. 1: Appearance of new curved-mask type color tube. Three electron guns are used.

LAST month Bruce A. Coffin, president of the CBS-Hytron Div. of Columbia Broadcasting System, Inc., announced at the Danvers, Mass. plant, that a new color TV tube, called the CBS-Colortron was being readied for production. The new tube, a product of more than two years of research and development, is a three-gun, color mask type that features a curved rather than a flat type mask to eliminate or minimize color misregistrations (convergence) at the outer edges of the raster. The method of applying color phosphors in the new tube employs a photographic technique that permits a considerable speed-up in production as contrasted to the flat-mask type. Mr. Coffin indicated that when CBS-Hytron plants were in "full-production" costs for the Colortrons might be about 30% more than for an equivalent sized aluminized black and white tube at the time. The company's Newburyport, Mass., plant is scheduled to be in pilot production by Feb. 1954 with color facilities at the new Kalamazoo, Mich., plant swinging into operation around Sept. 1954. Conditions of "full-production" are not expected to be reached until mid 1956. The new color tubes can be built in any of the existing black-and-white sizes, either round or rectangular but current emphasis is toward the 21-in. rectangular type.

Construction Details

Fig. 3 contrasts constructional details of a 15-in. round type tube employing a flat-mask against those of the new tube employing the curved mask. The planer or flat color mask assembly weighs about 6.5 lbs. as contrasted to less than 0.5 lbs. in the new type. In the flat-mask tube a spacer frame keeps the metal mask tightly stretched at an equal distance from the flat glass phosphor plate and holds the mask so that all of the 250,000 holes are in perfect register with the phosphor dot color triads. In the Colortron, three glass teats fused directly on the face plate of the tube provide 120° suspension points for the curved mask which has "V"-shaped receptacles in the metal mask ring. The degree of curvature is, of course, determined

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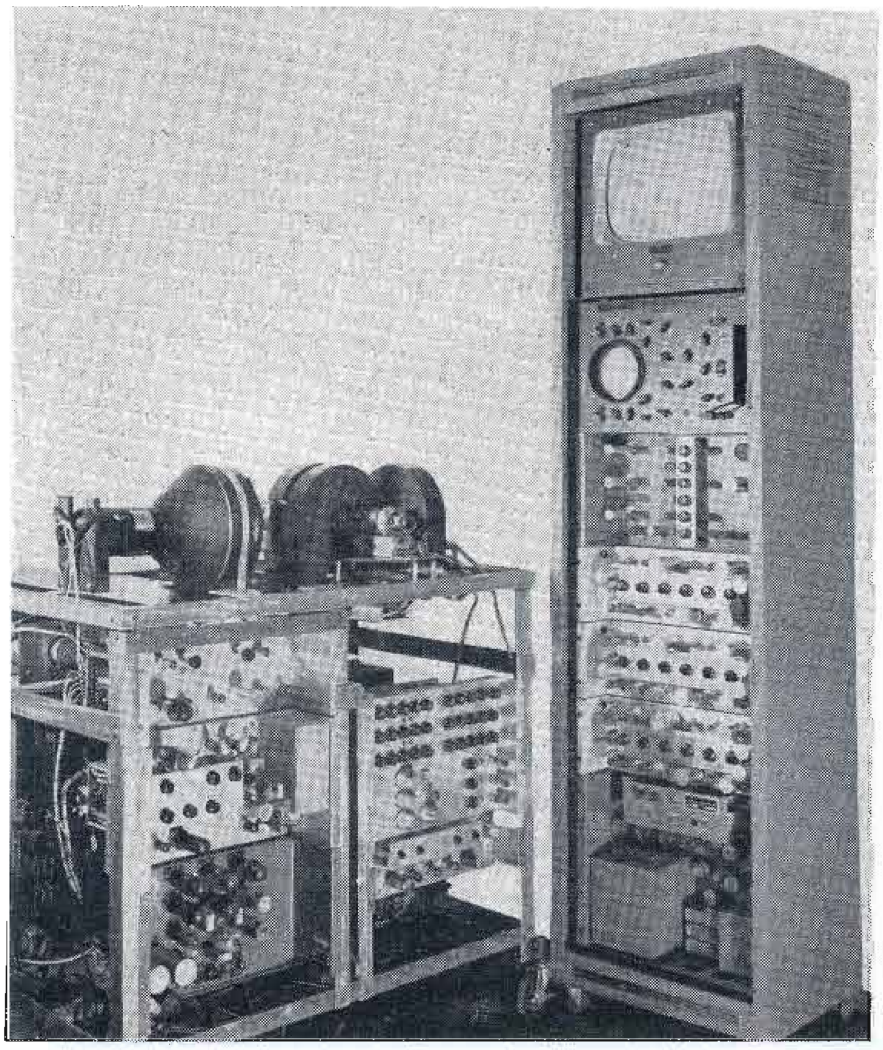


Fig. 2: View of new "Chromacoder" announced by CBS. Unit is designed to work in conjuction with singletube camera having field sequential pickup. Signals are then converted in this unit to simultaneous red, green and blue, for NTSC transmissions

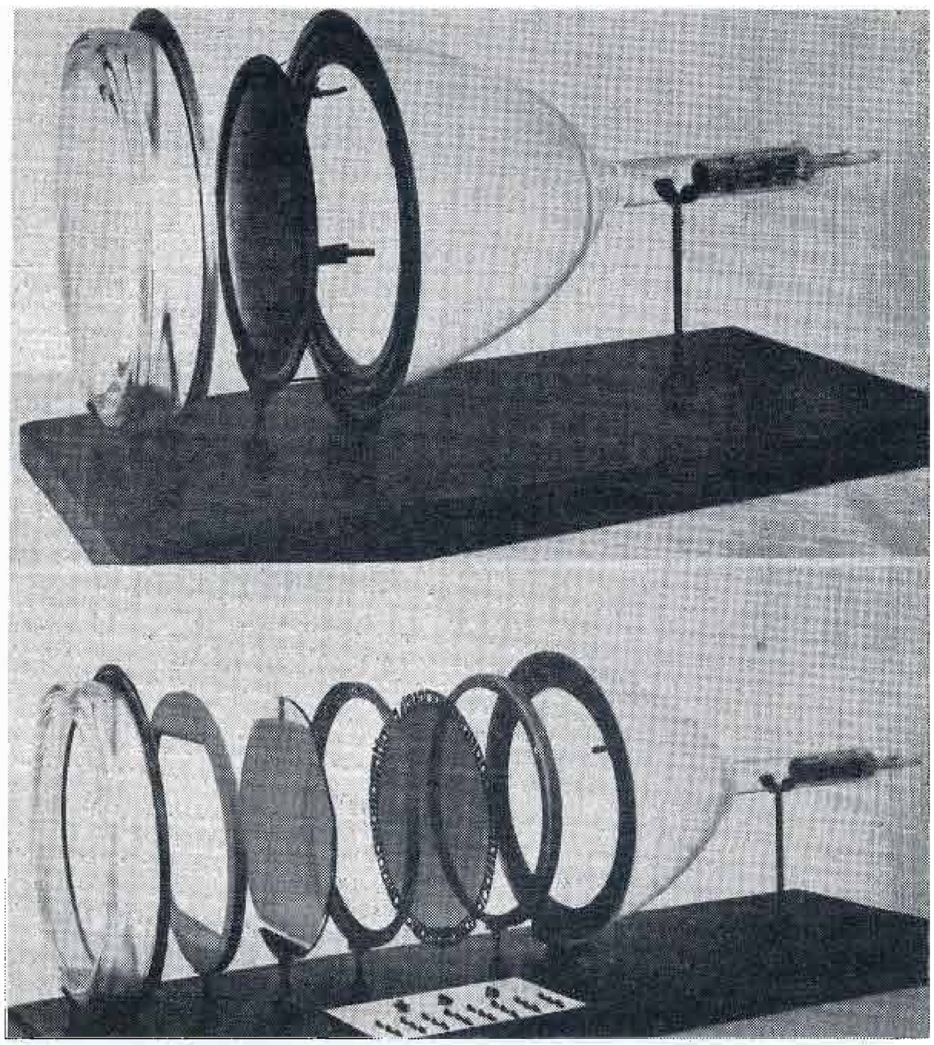


Fig. 3: Comparison of earlier flat-mask color-TV tube design (below) with new curved-mask type (above). The new tube can be built in any of the existing black-and-white tube sizes but currently production is being geared for 21-in. rectangulars

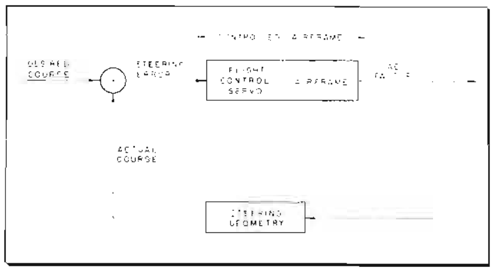


Fig. 1: Block diagram of flight system. Outer loop is steering, inner loop is control servo

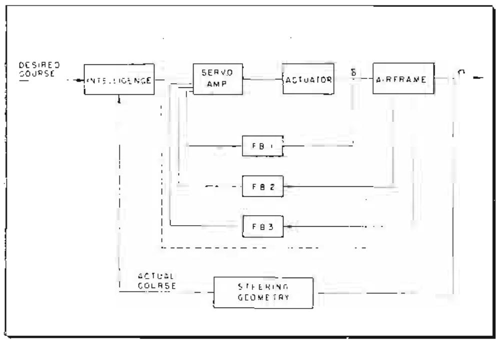


Fig. 2: To determine flight characteristics, both control servo and airframe are combined

Servo Design for Missile

How system is evolved from specification to component compensation. What the electronic engineer must know about mechanics and aerodynamics

By ROBERT J. BIBBERO and *ROLAND GRANDGENT*
Head, Servomechanisms Dept. *Principal Aerodynamicist*
Republic Aviation Corp., Guided Missiles Div., 99 Church St., New York, N. Y.

PERHAPS the most significant development in airborne electronics today is its tendency to grow away from purely electrical considerations and to merge with other fields of engineering. A radio engineer engaged in the design of airborne electronic systems does not restrict himself by specialization, but, instead broadens his interest to include such widely diversified fields as heat transfer, reliability and noise statistics, shock and vibrational mechanics, and many others.

This is particularly true in the study of the control and navigation of aircraft. In the design of those elements which make up the steering loop of a directed aircraft the principles of aerodynamics and flight mechanics must be applied to complete a successful system, as well as those of conventional electronics and of electrical or mechanical engineering.

The reasons for this statement become apparent when it is applied to the technology of guided aircraft and missile flight control. Although the basic steering intelligence of a guided missile may be derived from something as tenuous as electromagnetic radiation, it must ultimately be converted within the flight control mechanism to a force capable of deflecting a relatively massive control member, such as a wing or flap, a jet vane, or a gimballed motor.

Occupying a central position in the steering sequence is what we may term the flight control servomechanism or more simply, the servo. This device is a machine which accepts at low power levels inputs proportional to some combination of the aircraft steering error and its derivatives and to the airframe motion and its derivatives. Its outputs are control deflections which are directly, or through their derivatives, proportional to a summation of the inputs. The flight control servo-mechanism has also been called a servopilot, since it duplicates many functions of the human pilot. It is similar in many respects to the autopilot, although this term is better reserved for the device used in piloted aircraft.

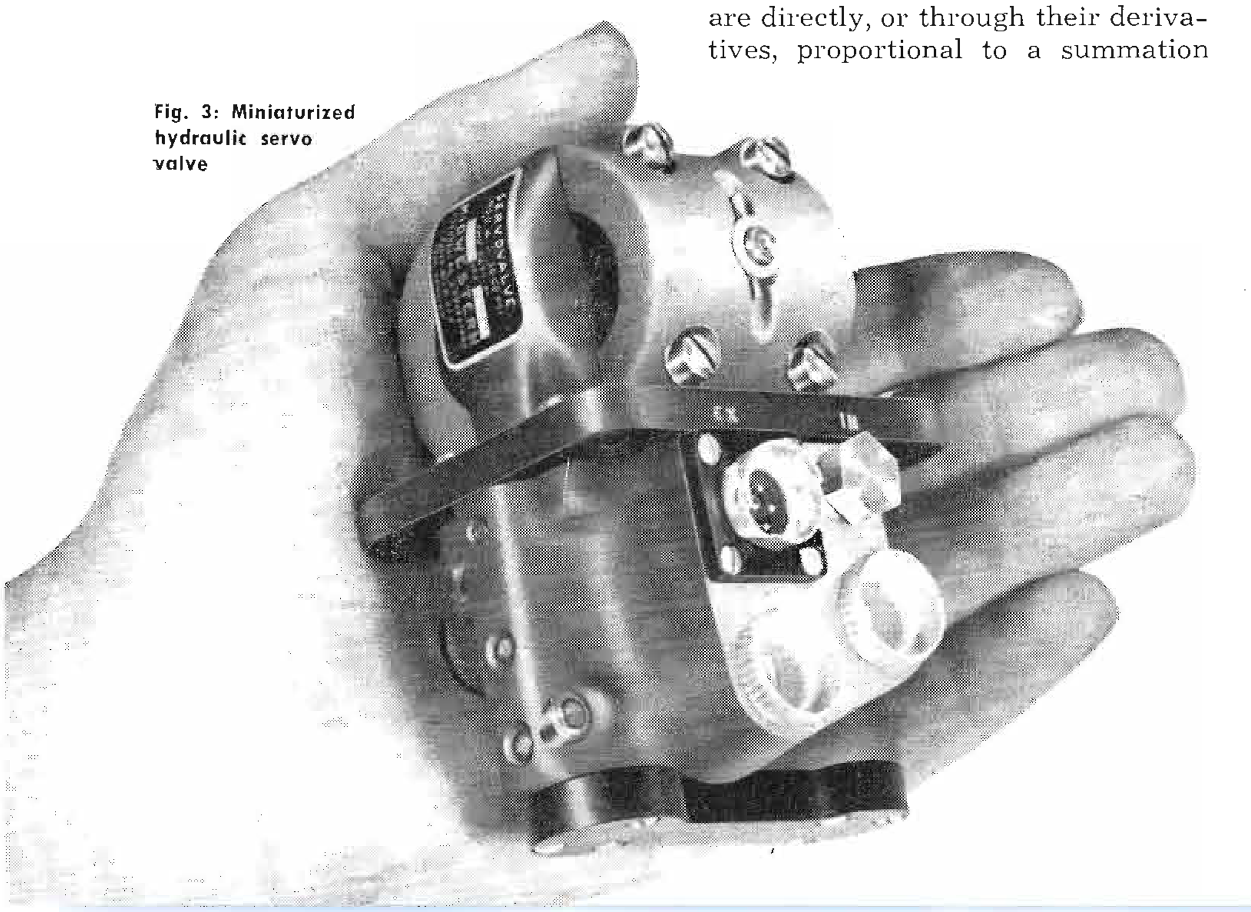


Fig. 3: Miniaturized hydraulic servo valve

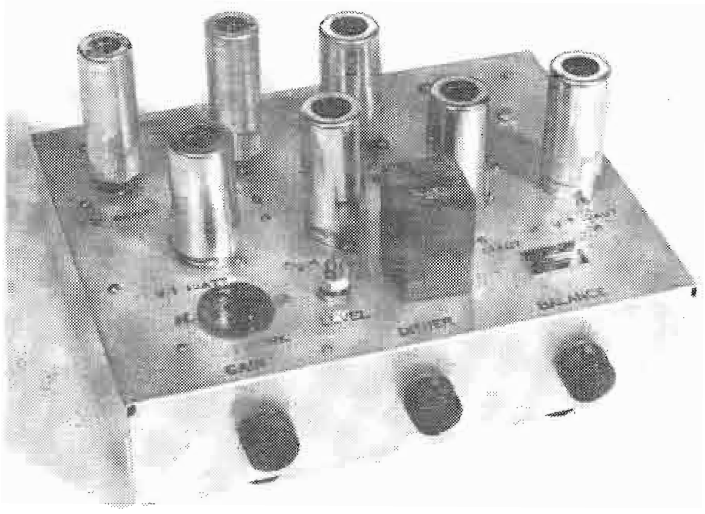
Elements to Include

An illustration may serve to clarify the exact elements which we wish to include in the flight control servo. We can consider a radio controlled drone aircraft or missile as an example. By means of some intelligent device capable of measuring the steering error, that is the difference between actual and desired aircraft course, a command which is a function of that error is computed and transmitted to the aircraft. The command is conveyed to a servo which deflects a control surface in an amount and direction proportional to the signal. If the steering equation requires that the airframe respond in a particular way to the command, it may be necessary to add other inputs to the servo. For example, if the command is to correspond to airframe rate of turn, the output of a rate gyro should be added. If it is to correspond to airframe lateral acceleration or load factor, the additional input may be a linear accelerometer. All of these devices are integral parts of the flight control servomechanism.

The general scheme just outlined can be expressed in block diagram form. (Fig. 1). The diagram consists of an outer loop and a number of inner loops. The innermost loop and the transducers responding to the airframe dynamics are what we have defined as the flight control servo. The outermost loop is the steering loop.

Although the conventional autopilot using a human pilot as the primary intelligence device is similar to the flight control servo, we prefer to regard it as a separate class

and Aircraft Flight Control



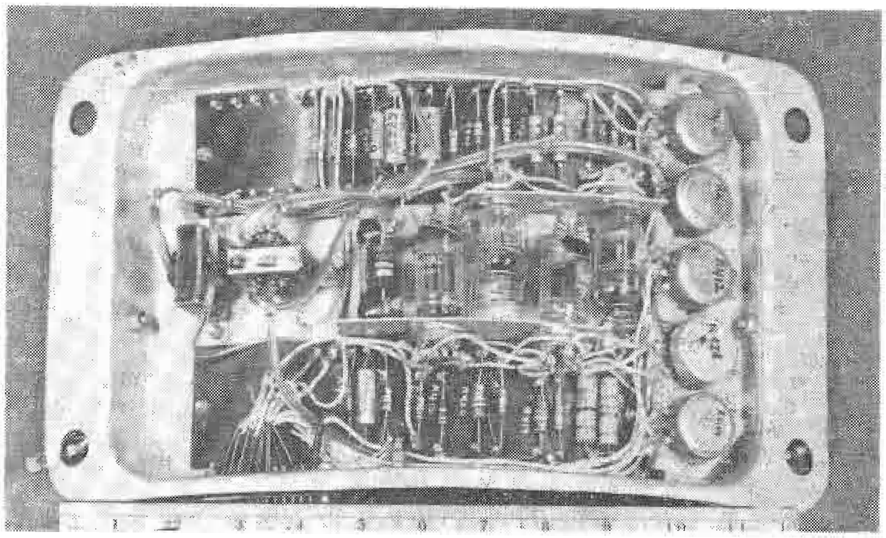


Fig. 4 (l) Typical servo amplifier breadboard. Fig. 5: (r) Final model of servo amplifier ready for flight test

for reasons of its performance and historical development. The autopilot was originally developed as a means of relieving the pilot during straight and level flight. As such, its primary duty is to respond to transient loads imposed by gusts and to compensate for steady-state loads developed by cross-winds and control surface malalignment. The piloted aircraft is stable under most flight conditions, hence the autopilot has a comparatively easy task to maintain favorable steady-state conditions.

Airframe Performance

On the other hand, the flight control servo built into a guided missile or pilotless aircraft is designed to operate primarily in the maneuvering condition. The airframe may be constructed with little inherent stability since in that way the highest maneuverability is obtained. Hence, the flight control servo must often provide stability as well as maneuverability to the airframe.

Historically, the first autopilots were designed with no particular airframe in mind, but with regard only to their own performance. The aircraft manufacturer chose from the available models those which best suited his airframe. In a later stage of development, the autopilot manufacturer became forcibly aware of the difference in dynamic response of various airframes and began to design the autopilot specifically for the characteristics of a particular airplane. In fitting the autopilot to a frozen design, inevitable compromises were made and the result was not always as desired.

In the final analysis, the flight control mechanism and the airframe should be designed together and to complement each other. When this is done, the system performance is optimum, regardless of whether the aircraft is intermittently or totally pilotless. At the risk of oversimplifying, it is our purpose here to delineate this ideal design process.

The authors have carefully examined the design processes actually employed in various flight control developments of which they have knowledge. Considerable progress has been made in the past ten years. However, early efforts were hampered by great difficulties of component development and manufacture which tended to distract attention from more fundamental problems. All too often the performance of the system as a whole was the last thing to be considered, whereas logically it should be the first. Many guided missiles, for example, evolved around components whose mechanical, electrical, or aerodynamic niceties attracted interest quite apart from the problem to be solved. Frequently, the understandable desire to use familiar techniques and components weakened any attempt to relate the design to the task logically. Today, however, the art has reached a state in which the designer can resist the preoccupation with components per se and focus attention on the system.

In the initial stages of design, it is necessary to establish the type and source of steering intelligence and the basic geometry of the steering process. These factors are determined from consideration of the task to be accomplished and the tools which come to hand. For example, in the case of a guided missile, the source of intelligence will depend on whether the target can best be observed by radar, visually or by other means; whether it is stationary or moving; and other factors of this nature. In steering geometry or navigation, we have a choice of beam-riding, homing, and precomputed trajectory, as well as combinations of these methods. The location of the intelligence source, whether on or off the airframe, also affects the geometry directly. The selection of the source of intelligence and the steering geometry are mutually interdependent and their problems should be considered together.

In a similar manner, the steering geometry and the airframe configuration are interdependent. A configuration entirely satisfactory for a beam riding missile might be very poor for a homing missile, and vice versa.

Loop Transfer Function

In considering the major steering loop it is advisable to determine first the characteristics of the combined control system and airframe, without commitments as to the physical nature of either. The two are considered mathematically as a single block. (See Fig. 2). The objective is to find a transfer function for the steering loop such that the system response to inputs and disturbances reduces the steering error in the desired time. Knowing the characteristics of the feedback path (the steering geometry) and the closed loop transfer function, the transfer function of the forward path (the control system plus airframe) is automatically determined. The for-

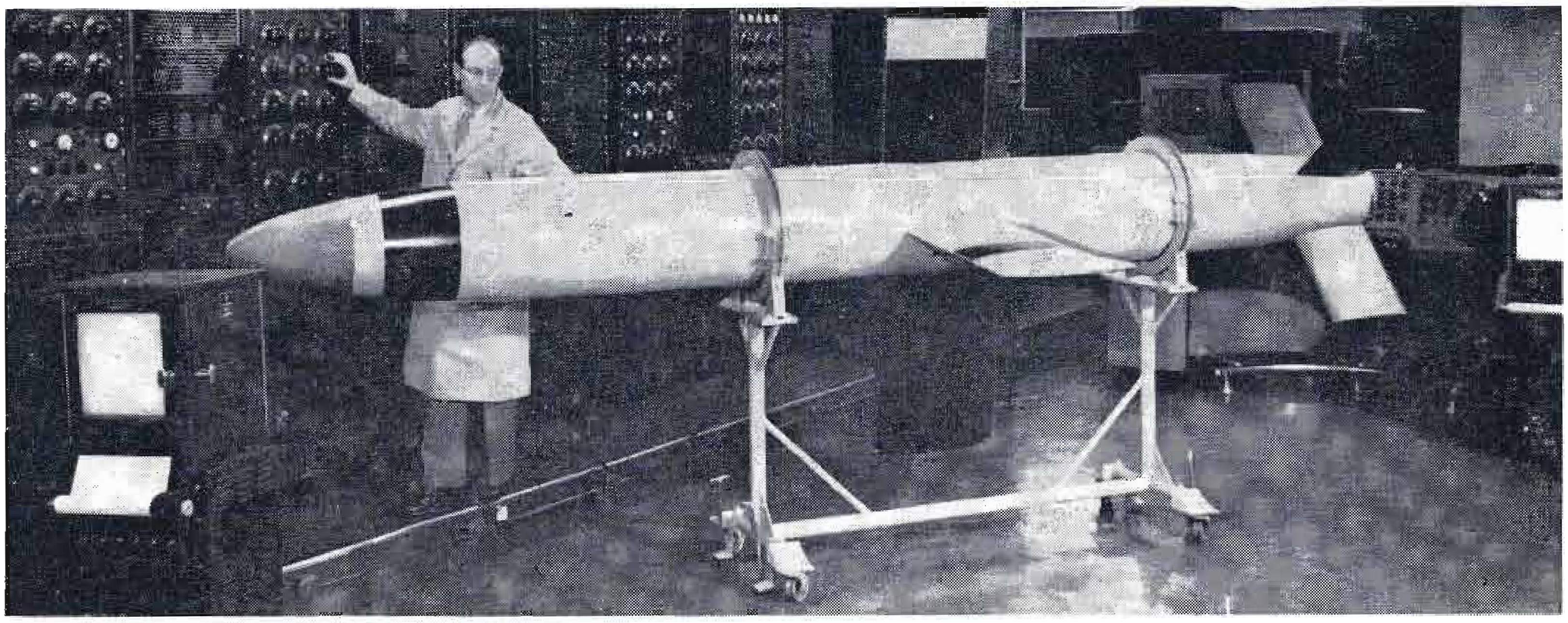


Fig. 6: Missile servo system test made through flight simulation is carried on in the laboratory of Project Cyclone

ward transfer function is the ratio of the airframe load factor (the "g"s pulled) to the steering error; the feedback circuit or steering geometry converting the airframe load factor to a quantity whose dimensions are the same as those of the input.

Having determined the transfer function of the combined control system and airframe, we can proceed to the manner of achieving the performance in terms of the separate characteristics of the control system and the airframe. At this point, a judicious selection of airframe characteristics may materially simplify the task of the control system.

Operational Requirements

In general, the design of the airframe is subject to many considerations not directly related to steering. Payload, range, structural requirements, and propulsion method may exert great influence on the configuration. However, the selected intelligence and steering geometry must not be overlooked during the airframe design. For given requirements on range, payload, and so forth, there are available many types of airframe configurations; some are well suited to one steering system, some to another. For example, if the intelligence is a self-contained angular-sensing device, like a radar homing head, it is important to employ a configuration in which steering is accomplished without excessive angular motions of the airframe axis. If this is not done, the "noise" introduced by the airframe angular motion may overwhelm the small angular signal which represents the target motion. Furthermore, in such cases, the feedbacks utilized in the flight control servomechanism must be carefully selected so as to provide whatever static stability or damping may be required, to enable the intelligence equipment to operate accurately.

The division of duties between airframe and flight control servomechanism require the utmost in cooperation between the aeronautical designer and the control system designer. Between them, they must arrive at two separate transfer functions that in cascade have the transfer function required of the complete forward path of the steering loop.

When this is done, the major characteristics of the two sub-systems are solidified. On the one hand we obtain the general aerodynamics and mass parameters (weight, moment of inertia, etc.) of the airframe, and on the other, the nature of the dynamic inputs to the flight control servo, such as transverse acceleration, angular velocity, angle of attack and so forth. It remains to design the flight control servo to the derived requirements.

This may be done initially by considering the servo controller and feedback elements as simple gains. Using elementary servo theory the output of the control servo-airframe cascade may be analyzed in response to some extreme frequency component of the intelligence output. Knowing the phase lags and amplitude ratio for the cascade needed to achieve the necessary following accuracy, the static gain and damping contributed by the servo can be calculated. If the analysis is extended to cover all input frequencies the usual Bode or Nyquist plots can be drawn and the phase and gain margins measured. However, the value of this type of analysis is somewhat questionable at this point since the computation must be repeated for each point on the flight path where the airframe transfer function parameters undergo a significant change. Furthermore, the traditional frequency analysis tacitly assumes that the transfer function is not time-varying, which is not always the case in the real airframe. The coefficients of the differential equation describing the aerodynamics are not constant, but vary with altitude and velocity. Hence, the frequency analysis is strictly applicable only in the case where these parameters do not vary with time.

Computer Analysis

Rather than complete the frequency analysis, the recommended technique is to set up the equations of motion of the airframe and of the simplified servo on any of the common varieties of electronic analog computer. The aerodynamic parameters can be modified quickly and easily on these machines to correspond to velocity and altitude. The servo gains can be varied about the values found by hand calculation; and finally, the effect of a finite servo time constant can be investigated, starting with a value about one-half to one-fourth that of the airframe. The input to the servo should be simulated by a step-function or combination of a step-function and slow ramp-function. If available, records of actual noise

(*Continued on page* 151)

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Latest listings of manufacturers names, addresses, telephone numbers and principals to contact for microwave products.

Adler Communications Labs., 1 LeFevre Lane, New Rochelle, N.Y. Harold Danson, 6-1620, Communication Equipment

Airborne Instruments Lab. Inc., 160 Old Country Road, Mineola, N.Y., H. DuVal, Garden City 3-0600, Microwave Components

Airtron, Inc., 20 E. Elizabeth Ave., Linden, N.J., Al Paulson, LI 3-8101, Waveguides

Allied Research & Engineering, Inc., 6916 Santa Monica Blvd., Hollywood 38, Calif., A. P. Chieves, HOllywood 2-1251, Waveguides

American Phenolic Corp., 1830 South 54th Ave., Chicago 50, Ill. W. H. Rous, Bishop 2-1000, Coaxial Cables, Connectors

American Silver Co., 36-07 Prince St., Flushing 54, N.Y., Herbert Schwartz, FL 3-8012, Clad Rolled Brass For Flexible Waveguides

Amperex Electronic Corp., 230 Duffy Ave., Hicksville, L.I., N.Y. Sam Norris, Hicksville 3-6200, Magnetrons, & Power Tubes

Andrew Corp., 363 East 75th St., Chicago 19, Ill., R. P. Lamons, TRiangle 4-4400, Xmission line Antennas, Waveguides

Autel Electronics Co., 1947 Farmingdale Rd., Westfield, N.J., A. H. Uminski, WEstfield 2-4434, Microwave Assemblies

Bendix Aviation, Red Bank Div., Eatontown, N.J., N. P. Barny, Eatontown 3-1340, Motors, Communications

Berkeley Div., Beckman Instruments, Inc., 2200 Wright Ave., Richmond, Calif. H. A. Stearns, LAndscape 6-7730, Frequency Meters

Bird Electronic Corp., 1800 E. 38th St., Cleveland 14, Ohio, Wm. Widler, Express 1-3535, Coax Equipment, Meters

Blaw-Knox Co., 2038 Farmers Bank Bldg., Pittsburgh, Pa., AT 1-5700, A. Jackson, Towers

Bogart Mfg. Corp., 315 Seigel St., Brooklyn 6, N.Y. David Krieger, HY 7-4972, Microwave Components & Assemblies

Bogue Electric Mfg. Co., 52 Iowa Ave., Paterson 3, N.J., R. P. Irwin, LA 5-2200, Generators, Controls

Bomac Laboratories, Inc., Salem Rd., Beverly, Mass., Earl Benson, Bev 4670, Magnetrons, TR Tubes, Thyratrons

Boonton Radio Corp., Boonton, N.J., F. G. Marble, Boonton 8-3200, Signal Generators

Bristol Engineering Corp., Lincoln & Pond St., Bristol 1, Penna., R. J. Zeigler, Pulse Equipment

Browning Laboratories, Inc., 750 Main St., Winchester, Mass., R. L. Purrington, WI 6-3700, Test Equipment

Budelman Radio Corp., 375 Fairfield Ave., Stamford, Conn., F. T. Budelman, Stamford 48-9231, Microwave Radio Systems

Cannon Electric Development Co., 3209 Humboldt St., Los Angeles 31, Calif., D. A. Davis, CA 5-1251, Signal Systems

Canoga Corp., 5955 Sepulveda Blvd., Van Nuys, Calif., P. H. Ryckoff, State 5-8694, Radar Equipment

Cascade Research Corp., 53 Victory Lane, Los Gatos, Calif., J. S. Jaffe, EL Gato 4-1305, Xmission line, Amplitude Modulator, Oscillator

Century Electronics Div., Century Metalcraft Corp., 14806 Oxnard St., Van Nuys, Calif., E. T. Steele, ST 7-1178, Microwave Equipment

C.G.S. Laboratories, 391 Ludlow St., Stamford, Conn., C. G. Sontheimer, Test Gear, Microwave Oscillators

Coaxial Connector Co., 35 North Second Ave., Mount Vernon, N.Y., Larry Willis, Mount Vernon 8-6416, Waveguide Components

Communication Products Co., Inc., Freehold, N.J., J. Bernard, Freehold 8-1880, Communication Equipment, Coax

Corning Glass Works, New Products Div., Corning, N.Y., George Norman, COrning 6-3271, Microwave Components

Cubic Corp., 2841 Canon St., San Diego 6, Calif., D. E. Root, Academy 2-8191, Calorimetric Wattmeters, Standing Wave Amplifiers

Dalmo Victor Co., 1414 El Camino Real, San Carlos, Calif., J. A. Chartz, Lytell 3-3131, Radar Antennas, Microwave Components

Daven Co., 191 Central Ave., Newark 4, N.J., George Newman, MI 2-6555, Indicators, Meters, Attenuators

DeMornay-Bonardi, 3223 Burton Ave., Burbank, Calif., R. E. DeMornay, RO 9-2049, Microwave Equipment

Diamond Micowave Corp., 7 North Ave., Wakefield, Mass. J. S. O. Gallaghan, Cr 9 2200, Microwave Components, Test Equipment

Dorne And Margolin, Inc., 30 Sylvester St., Westbury, L.I., N.Y., C. D. Berger, WEstbury 7-3200, Microwave Test Equipment

Douglas Microwave Co., 338 E. 95th St., New York 28, N.Y., R. H. Douglas, TRafalgar 6-6095, Radar & Microwave Components

Dresser-Stacey Co., IDECO Div., 875 Michigan Ave., Columbus 8, Ohio, Towers

DuMont Laboratories, Inc., Allen B., 1500 Main Ave., Clifton, N.J., C. J. Harrison, MUlberry 4-7400, Microwave Relay Links

Dynamic Electronics-New York, Inc., 73-39 Woodhaven Blvd., Glendale, L.I., N.Y., J. D. Winer, ILlinois 9-7000, Resonance Indicator, Field Intensity Equipment

Eitel-McCullough, Inc., San Bruno, Calif., O. H. Brown, Juno 8-1212, Microwave, Tubes, Klystrons

Electrical Tower Service, Inc., 206 S. Washington St., Peoria, Ill., S. Bernstein, 3-9846, Microwave Towers

Electro-Impulse Laboratory, 62 White St., Red Bank, N.J., Irving Rubin, Red Bank 6-0404, Microwave Generators, Meters

Electro Precision Products Inc., 119th St. & 20th Ave., College Point 56, L.I., N.Y., F. K. Clark, FLushing 8-1795, Waveguide Assemblies

Emerson Electric Mfg. Co., 8100 W. Florissant, St. Louis 21, Mo., R. T. Queen, CO 1800, Microwave Equipment

Empire Devices Products Corp., 38-15 Bell Blvd., Bayside 61, N.Y., M. T. Harges, BAyside 4-8500, Microwave Attenuators

Engineering Associates, 434 Patterson Rd., Dayton 9, Ohio, WAlnut 1662, Microwave Test Equipment

Espey Mfg. Co., 528 E. 72nd St., New York, N.Y., Nathan Pinsley, TR 9-7000, Microwave Equipment

Federal Telecommunication Laboratories, Div. of Int'l. Telephone & Telegraph Corp., 500 Washington Ave., Nutley 10, N.J., S. Metzger, Nutley 2-3600, Microwave Links

Federal Telecommunications Labs., Inc., TV Branch, Rt. 17, Lodi, N.J., R. G. Bach, Hubbard 8-8440, T. V. Microwave Links

Federal Telephone & Radio Corp., 100 Kingsland Rd., Clifton, N.J., Wm. P. Maginnis, NU 2-3600, Communication Equipment

Ferris Instrument Co., Boonton, N.J., H. J. Tyzzer, Boonton 8-0781, Signal Generators, Frequency Calibrators

Freed Transformer, 1718 Weirfield St., Brooklyn 27, N.Y., EV 6-1300, Test Equipment

Frequency Standards Corp., P.O. Box 54, Asbury Park, N.J., H. Burr, Asbury Park 1-1718, Frequency Meters

Garod Radio Corp., 70 Washington St., Brooklyn, N.Y., Maurice Raphael, UI-2-6000, Radar Test Racks

General Communication Co., 681 Beacon St., Boston, Mass., J. B. Hamre, CO 7-6030, Microwave Test Equipment

General Electric Co., Tube Div., Schenectady 5, N.Y., John Nelson, 4-2211, Microwave Tubes

General Electric Co., Commercial Equipment Div., Electronics Park, Syracuse, N.Y., P. L. Chamberlain, 76-4411, Microwave Relays

General Radio Co., 275 Massachusetts Ave., Cambridge, Mass., R. E. Bard, TR 6-4400, Test Equipment

General Precision Laboratory Inc., 63 Bedford Rd., Pleasantville, N.Y., E. H. Lombardi, Pleasantville 2-2000, Microwave Components

General RF Fittings Co., 702 Beacon St., Boston 15, Mass., F. E. Marshall, KE 6-2290, Microwave Components

Gertsch Products, Inc., 11846 Mississippi Ave., Los Angeles 25, Calif., E. P. Gertsch, Frequency Meters

Gilfillan Bros., Inc., 1815 Venice Blvd., Los Angeles 6, Calif., Sennett Gilfillan, DU 7-5131, Microwave Equipment

G & M Equipment Co., 7315 Varna Ave., North Hollywood, Calif., Austin Montgomery, Poplar 5-4185, Microwave Test Equipment

Gombos, Inc., John, 103 Montgomery St., Irvington, N.J., J. Gombos, ES 3-6633, Microwave Components

Hewlett-Packard Co., 395 Page Mill Rd., Palo Alto, Calif., W. N. Eldred, DA 5-4451, Test Equipment

Huggins Laboratories, 711 Hamilton Ave., Menlo Park, Calif., R. A. Huggins, DA 2-0346, Traveling Wave Tubes

Hycon Mfg. Co., 2961 E. Colorado, Pasadena, Calif., R. F. Crisp, SYcamore 5-4241, Microwave Components

Instrument Specialties Co., Inc., Bergen Blvd., Little Falls, N.J., J. D. Roberson, Little Falls 4-0280, Microwave Development Kits

Jones Electronics Co., M. C., 96 N. Main St., Bristol, Conn., M. C. Jones, Power & SWR Measuring Equipment

Kay Electric Co., 14 Maple Ave., Pine Brook, N.J., L. A. Garten, CAldwell 6-4000, Test Equipment

Kellogg Switchboard & Supply Co., 79 West Monroe St., Chicago 3, Ill., J. G. Beckley, DEarborn 2-0750, Microwave Terminating and Signalling Equipment

Kent Co., F. C., 64 Howard St., Irvington, N.J., W. H. Kean, Jr., Essex 3-5500, Waveguides

Kings Electronics Co., 40 Marbledale Rd., Tuckahoe 7, N.Y., W. R. Clayton, Tuckahoe 3-8770, Waveguide Components, Test Equipment

Kinney Co., Joseph, Rosslyn Road, Carnegie, Pa., Joseph Kinney, Jr., Walnut 2-1226, Rectangular Waveguide

Kline Iron & Metal Co., 1225-35 Huger St., Columbia, S.C., Towers

Laboratory for Electronics, Inc., 75 Pitts St., Boston 14, Mass., M. C. Lewis, R 12-3200, Microwave Oscillator

Lavoie Laboratories, Inc., Morganville, N.J., F. K. Dederick, Matawan 1-2600, Radar Systems

Lear, Inc., 11916 W. Pico Blvd., Los Angeles 34, Calif., H. W. Upton, Microwave Equipment

Lenkurt Electric Co., 1105 Old Country Road, San Carlos, Calif., E. A. Hall, LY 3-2161, Communication Equipment

LIECO Inc., 147 Ocean Ave., Lynbrook, N.Y., A. Zeltz, Lynbrook 9-6920, Waveguide Assemblies, Microwave Test Equipment

Litton Industries, East Brittan Ave., San Carlos, Calif., C. V. Litton, LY 3-3757, Microwave Tubes

Luhrs & Co., C. H., 297 Hudson St., Haskensack, N.J., C. H. Luhrs, DI 2-4797, Microwave Switches, Coupler Modulators

Manson Laboratories, 207 Greenwich Ave., Stamford, Conn., S. Jacobson, Stamford 3-4624, Microwave Tubes, Waveguide Components

Mark Products Co., 3549 Montrose Ave., Chicago 18, Ill., E. F. Harris, IRving 8-5355, Microwave Antennas

Maxson Corp., W. L., 460 West 34th St., New York, N.Y., S. M. Skelst, LO 5-1900, Microwave Systems, Radars

Measurements Corp., Boonton, N.J., H. Houck, Boonton 8-2131, Test Equipment, Megacycle Meters

Mendelsohn Speed Gun Co., 457 Bloomfield Ave., Bloomfield, N.J., Samuel Mendelsohn, BL 2-1270, Coaxial Components

Mico Instrument Co., 80 Trowbridge St., Cambridge, Mass., R. F. Walker, Kirkland 7-8660, Coaxial Wavemeters

Microdot Division Felts Corp., 1826 Fremont, So. Pasadena, Calif., M. H. Lewis, Py 1-2782, Coaxial Connectors, Cable

Microlab, 301 S. Ridgewood Rd., S. Orange, N.J., H. Augenblick, South Orange 2-7422, Coaxial Attenuators, filters

Microwave Associates Inc., 22 Cummington St., Boston 15, Mass., D. W. Atchley, Jr., Copley 7-4441, Magnetron, TR & ATR Tubes

Microwave Development Labs., Inc., 220 Grove St., Waltham 54, Mass., T. S. Saad, Microwave Connectors

Motorola, Inc., 4545 Augusta Blvd., Chicago 51, Ill., E. S. Goebel, SP 2-6500, Microwave Systems

National Instrument Co., 23 East 26th St., New York 10, N.Y., H. L. Zell, MUrray Hill 3-1527, Microwave Switches

(Continued on page 149)

Expanding the Tape

Delayed broadcasts and special recordings may be handled efficiently with minimum station personnel. Inexpensive time clock and delay relay provide on-the-nose automatic operation

In many ways the tape recorder has quite recently become an indispensable item of equipment for the broadcast station. It is used regularly to delay broadcasts, for special events and news work, for reference recordings, for high-fidelity, scratchless recordings for FM broadcast and numerous other applications. The small station with a limited staff can ease the work load.

WINC is a 250-watt local station with a network affiliation. As in most net stations, it is necessary to DB or delay broadcast on several network programs weekly.

'n automatic tape starting device was designed and built, which has taken all the DB burden from the operator, and hasn't missed a program yet. When the operator comes on duty, he sets the controls for all DB recordings during his trick. The devices to be described do the rest.

By
PHILIP WHITNEY
Chief Engineer
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At WINC and WRFL (FM) three different types of Ampex tape recorders are used. Each has a different control and starting problem, so all three types (300, 400 and 400A) are covered here.

Automatic Start

The type 300 (floor model) is automatically started by two inexpensive time clocks and a time delay, thermally operated. This machine must first have the primary power applied, then, after warm-up, the motor is started, and lastly, the "Record" button is depressed. This order must be followed, and the starting of the tape travel and depression of the "Record" button cannot be simultaneous. A $5 electric time clock is set to apply the primary power to the recorder a few minutes before the second clock, a Telechron "House Timer," model 8H55, which cost less than $15 starts the time delay sequence. This second clock is remodelled by removing the 115 volts from the socket in the rear, and merely using the contacts in the clock as shown in Fig. 1. Since both of these clocks can only be set to 15-minute intervals, the

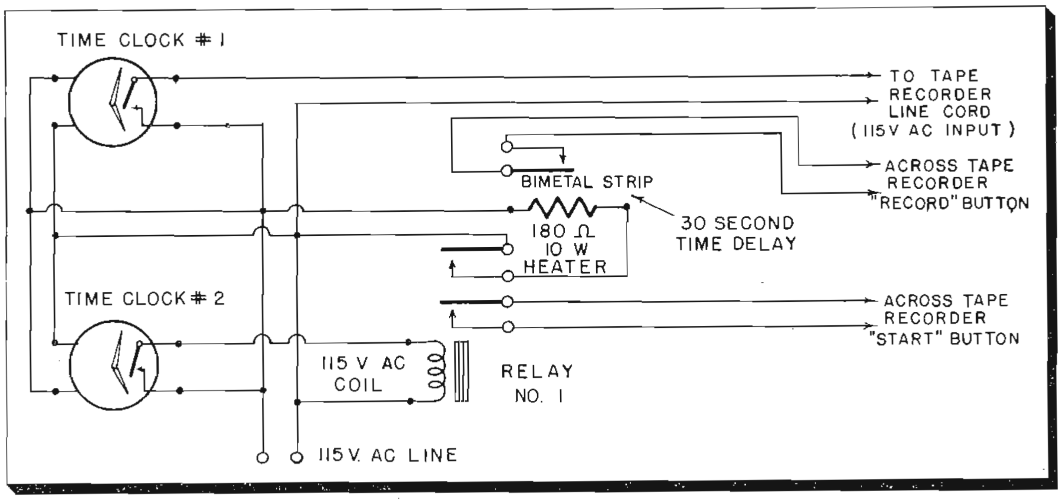


Fig. 1: Automatic starting system for a magnetic tape recorder

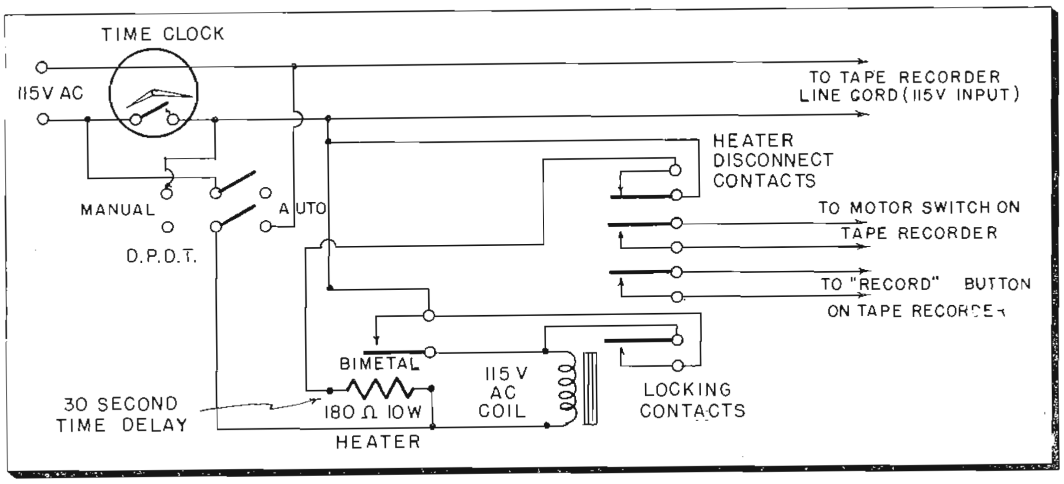
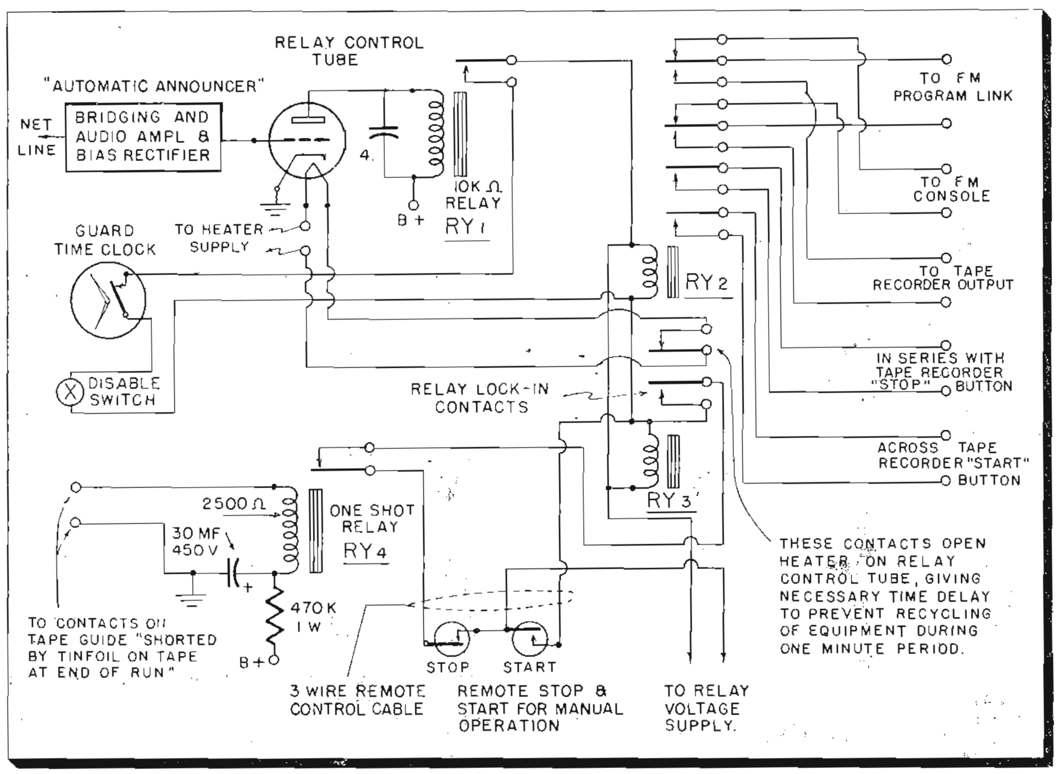


Fig. 2: Timer and clock arrangement for starting the Model 400 tape recorder

Fig. 3: Automatic and manual start-and-stop system used with "Automatic Announcer"



Recorder's Usefulness

first clock is set to run about 5 minutes fast, and the second is set about one minute or less fast. When the second clock applies power to the relay which closes the capstan relay on the tape recorder, it also applies power to a resistor which heats, causing a bimetallic strip to close in from 10 to 30 seconds, making the contact which, in effect, temporarily shorts out the "Record" button in the recorder. The recorder has been started in the recommended sequence, and runs until the tape runs out or it is stopped by the operator. The machine is equipped with a microswitch that shuts it down when the tape is expended.

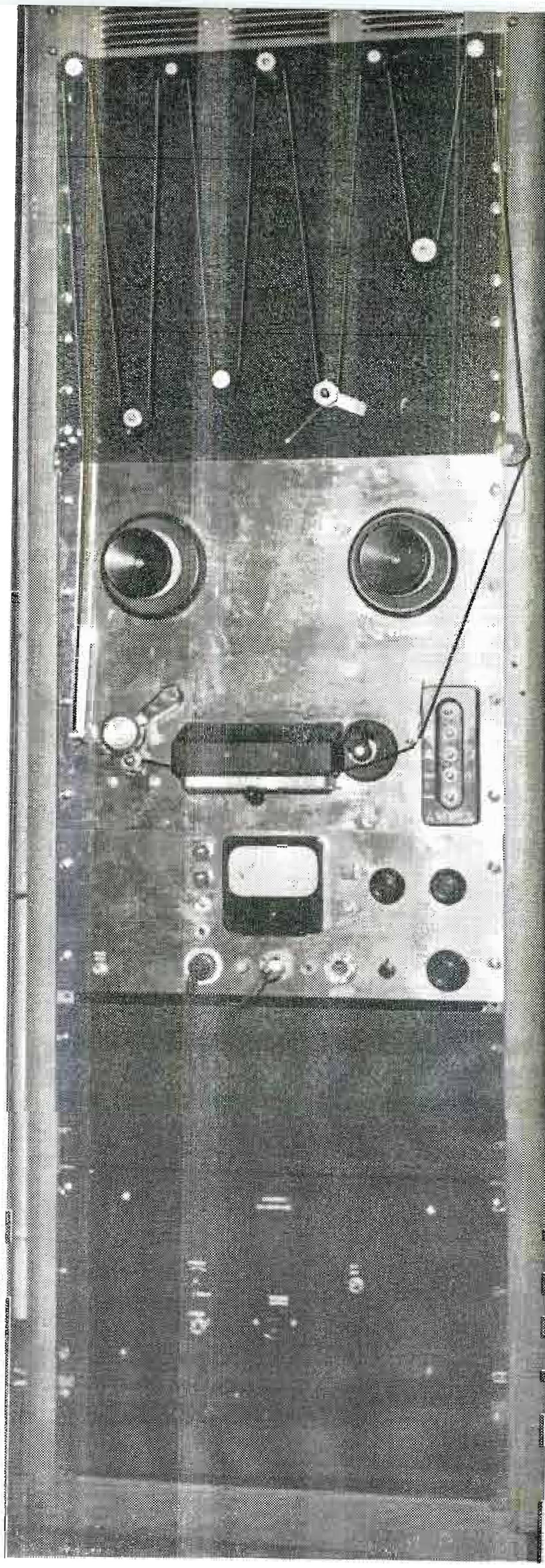
A table model 400 recorder is started by the timer and clock arrangement diagrammed in Fig. 2. The clock is another Telechron similar to the one described above. It is used as purchased with no changes. The socket on the back supplies 115 volts ac to the tape recorder and to the timing circuit when the clock is "on." To set up this recorder for

Pre-Operation Procedure

To set up this recorder for automatic start the power switch on the recorder's front panel is thrown "on," and the "Forward—off—rewind" arm on the top panel is engaged in the "Forward" position, with the top panel "power" switch (motor starting switch) left "off." The robot starter then applies power to the electronic portion of the recorder, allows it to warm up briefly, then shorts the motor starting switch and shorts the "Record" button. A switch on the starter allows the machine to be used normally when the automatic start is not needed. Here, the time delay is again a 180-ohm 10-watt resistor, to which is applied the 115 volts. When this heats, it curls a bimetallic strip, closing the contacts. Any other type of short time delay device, such as a synchronous motor timer may also be used, or with slight modification of the circuit, one of the thermal switches, such as are used in some TV boosters, might be used. This time delay allows the tubes to heat sufficiently in the recorder before the relay starts the motor and shorts the "Record" button. The time clock, of course, should be set about one minute fast, so that recording will have started on the hour or half- or quarter-hour segment which is to be transcribed. Since the clock will remove all power from the device and the starter at the end of the period selected, an additional 15 minute tab should be pulled to assure the recorder running for the full period. (It was set ahead, so will stop before the period is actually over). This simple arrangement has saved considerable money that could have been spent on more expensive equipment, and has done the job admirably. All cables that interconnect the automatic starter and time clock are attached to the tape recorder through a cable fitted with an octal plug and socket with covers, so that it can quickly be disconnected when the tape recorder must be used outside the station.

Automatic Announcer

The third machine is used in the FM station exclusively as an automatic announcer. The device plays on the air a continuous tape at every station break, giving call sign and a brief commercial. Since the wages paid to an announcer to make these announcements would far outweigh any revenue that sponsors can afford for FM, this equipment allows the FM station to realize income otherwise impossible. The continuous tape is strung over 10 sets of generator bearings provided with retaining washers on the sides, on a 2 x 2 ft. area in the rack directly above the tape recorder mounting. The tape automatically starts when the net or local program stops at a quarter- or half-hour time selected by a time clock as a guard circuit. The cessation of the program removes bias from a relay control tube having a plate relay in its circuit. The combination of the closed circuit of the time clock and this relay in series allow a set of relays to operate, switching program from the line to the output of the tape recorder, shorting out the "start" button on the model 400A. The tape is stopped and the program returned to the FM transmitter through the use of a small piece of tinfoil stuck on the tape, which shorts out a pair of contacts provided in one of the tape guides. This operates a "one shot" relay. (Operated by a slowly charged capacitor in series with a high resistance and the "B" supply). The length of the tape automatically times its own operation, and is set for about 25 seconds, giving a little leeway on a 30-second station break. This is an improvement over the original time delay relay circuit, since it simplifies the operation and



WRFL automatic chainbreak (center bay) for commercials, station breaks. Relays at bottom

the time delay is infallible. Since the output of the tape recorder in this instance is applied directly to the link to the FM transmitter, it is necessary to experiment with levels in recording the station identification and commercial, so that it will properly modulate the FM transmitter. Once the proper level is determined, it should be noted, and all future changes of commercial recorded to this same level. Fig. 3 illustrates how the tape recorder is started and stopped in conjunction with the "Automatic Announcer."

Design Factors That Extend

Results of field tests show effect of environmental conditions on tube reliability. How to keep cathode and bulb temperatures within safe limits

By JOHN H. WYMAN
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Eatontown, N.J.

THE need for tubes of the ultimate in reliability for aircraft control equipment makes it important to provide the design engineer with more data on the effect of various environmental conditions on tube life.

Life failures in electron tubes fall into two classes—the catastrophic, or short term, unpredictable type; and the type of failure in which a more or less gradual deleterious change occurs in some operating characteristic. The second type of failure we will designate long term. Eliminating the catastrophic type of failure is a problem for the design and quality control departments of the various *tube* manufacturers. The long term type of failure mentioned above, however, can be aggravated or ameliorated by the activities of *equipment* design engineers.

The long term life of a vacuum tube is directly dependent upon several factors among which are the following:

1. Processing
2. Purity of materials used
3. Design
4. Operating conditions

The first two are outside the scope of this article since the equipment design engineer must assume that his supplier of tubes has used the best possible choice of materials and processing economically available.

There are tubes of many different quality levels available on the market from which the engineer may choose. These include conventional receiving tubes with objectives of design of—at most—a few thousand hours of life; premium line tubes for approximately 10,000 hours; and very long life tubes for particular applications such as remote transmitters and undersea cables.

Factors Affecting Life

The long term life of a vacuum tube is directly dependent, among other things, upon:

1. Cathode temperature
2. Electrode temperatures
3. Bulb temperatures
4. Gas pressure within the envelope
5. Rate of evaporation of various materials within the tube
6. Rate of evolution of gases from parts of structure

These conditions are affected by operating conditions such as:

1. Heater voltage
2. Plate dissipation
3. Screen dissipation
4. Ambient temperature
5. Altitude
6. Vibration
7. Control grid impedance

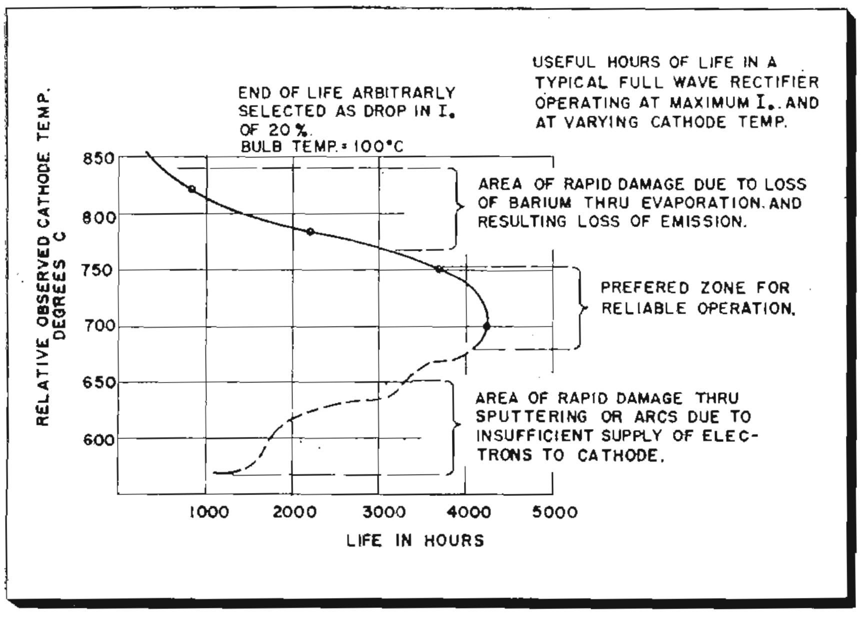
Fig. 1 shows the effect of cathode temperature on life for a rectifier. Above the safe operating range of 680°-750°C, the increased rate of evaporation of barium causes rapid loss of emission and thus failure. Operating the cathode at lower temperatures damages the tube if the current demand of the load is greater than the supply.

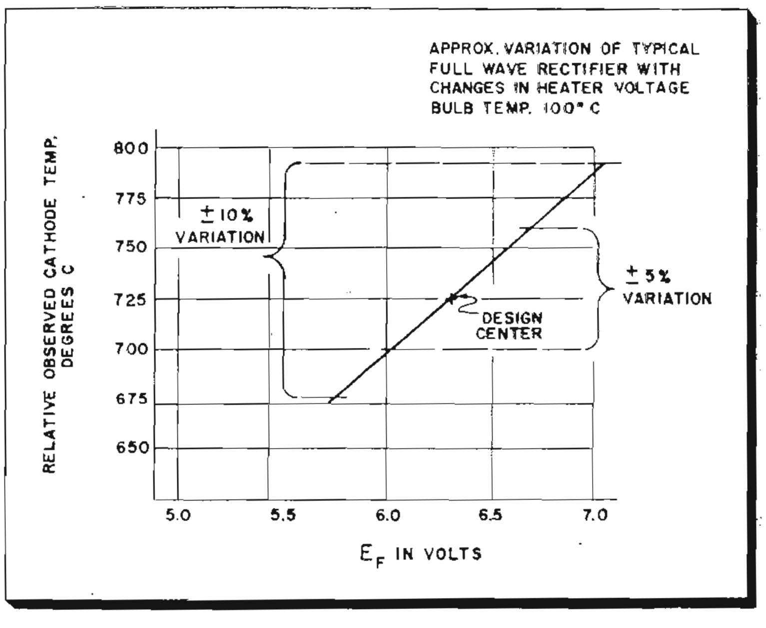
Cathode Temperature

Fig. 2 shows how cathode temperature is affected by heater voltage variations. From these two figures it is obvious why close control of the heater voltage should be maintained for long electrical life.

Fig. 3 shows what happens to the cathode temperature when the bulb temperature is raised by overloads arising from excessive plate or screen dissipations or heat from other components or lack of proper ventilation. It is obvious that a 100°C increase in bulb temperature above the design point can materially shorten the tube life. Tests have shown that simply enclosing a 6V6 in a box approximately one foot cubed at maximum dissipation will increase the bulb temperature by 40°C. Picture an enclosed electronic unit with 15 or 20 tubes and transformers. What temperature have you? Bulb temperatures as high as 400°-500°C have been recorded in some airborne equipment. In previous articles on this subject, the other effects of exceeding element dissipations have been discussed. (See TELE-TECH & ELECTRONIC

Fig. 1: (l) Effect of cathode temperature on life of a rectifier. Fig. 2: (r) Effect of voltage variations on cathode temperature





Electron Tube Life

INDUSTRIES, June 1953, page 127; July 1953, page 43.)

Fig. 4 shows the increase in bulb temperature resulting when a tube operating at constant dissipation is carried by an aircraft into rarefied atmosphere where cooling is reduced as the altitude increases. Obviously, if a tube is to operate reliably at higher altitudes, then it must have auxiliary cooling or its ratings must be reduced.

In addition to raising the cathode temperature, increasing the bulb temperature also results in release of gas from the glass. Gas release damages the cathode through the mechanism of positive ion bombardment. High bulb temperatures also cause vaporization of barium from the getter deposit which redeposits on colder spots such as micas causing grid leakage.

The control grid current due to collection of gas ions or to electrical leakage is in such a direction as to reduce the grid bias due to the IR drop in the grid resistance. This effect may cause excessive screen and plate dissipation if the grid resistance is too large.

Bulb Temperature

Receiving tubes use soft glass in their envelopes, and their upper safe operating temperature varies with the application, but for reliable operation of several thousand hours should not exceed *about* 165°C, and should be kept lower if possible. Hard glass, nonex, may offer higher safe operating temperatures. If the tube designs employ proper cathode temperatures (250-300°C) safe maximum bulb temperatures are possible.

Vibration Effect

Vibration has some very severe effects on the life of a tube. If the vibration of an aircraft or other vehicle is close to the resonant point of any of the parts of a tube structure, then destructive failure of micas, due to sawing, and of other parts due to fatigue and crystal growth will occur. Unfortunately, the various parts of the tube are of such configuration that they are resonant at frequencies in the very ranges that are experienced in aircraft. Destruction of micas from sawing by grid side rods or the cathodes occurs when these parts resonate. When micas disintegrate, the particles fall against the hot cathode and oxygen and other gases are released which damage the emission coating. Substitutes such as various synthetic micas and ceramics are under study as a replacement for mica.

Fig. 5 shows roughly the tube life as a function of magnitude of repetitive shock. The range of life for a given level of shock corresponds to the quality range of mechanical reliability that is available at this time. This chart is prepared from empirical data and is submitted only to show the general nature of the phenomenon.

Bulb temperatures can be measured with sufficient accuracy for equipment design purposes with "Tempilaq." "Tempilaq" is a trade name for one of a series of paints with closely controlled melting points. The paints can be applied directly to the bulb or other surface with a brush.

Vibration intensity can be measured by the use of an accelerometer of the type manufactured by the Gulton Co. These devices are made in the shape of a vacuum tube and may be plugged into the actual socket under study. The output is proportional to acceleration and may be read conveniently on a CRO.

Heat and vibration are the two major environmental enemies of long tube life. Almost all of the above listed operating conditions are related rather directly to these two environmental factors. Therefore, it is important that the equipment designer determine these environmental conditions for the contemplated tube and that the tube designer determine the environmental conditions suitable for the desired life of his tubes. Although heat and vibration environmental factors are not easy to define, cognizance of the above points is resulting in considerable improvement in systems reliability.

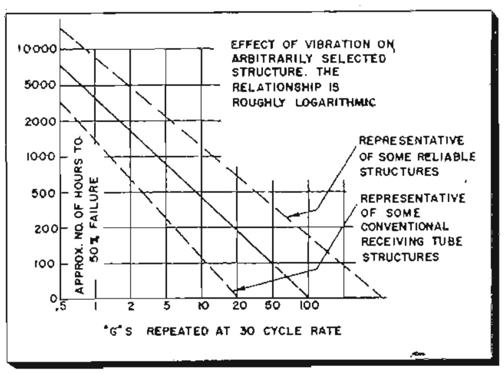
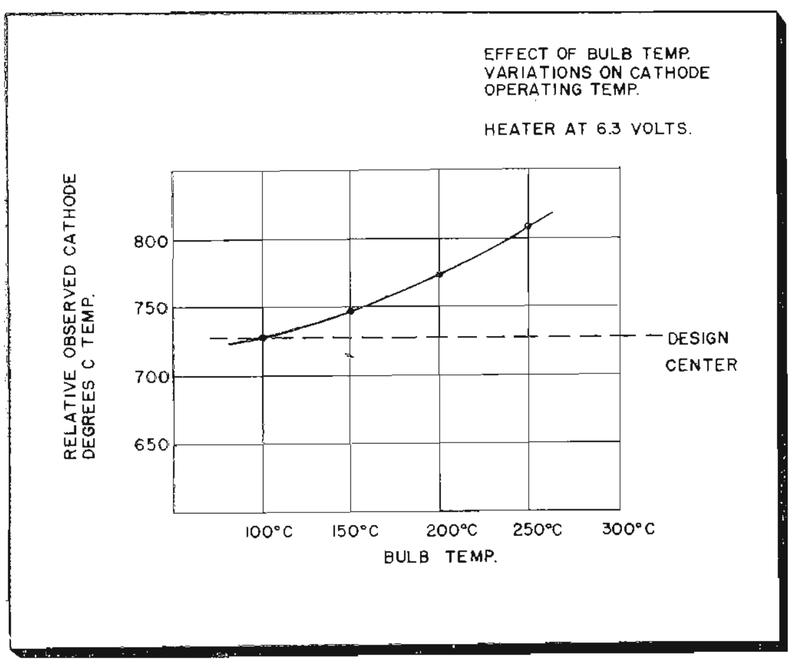
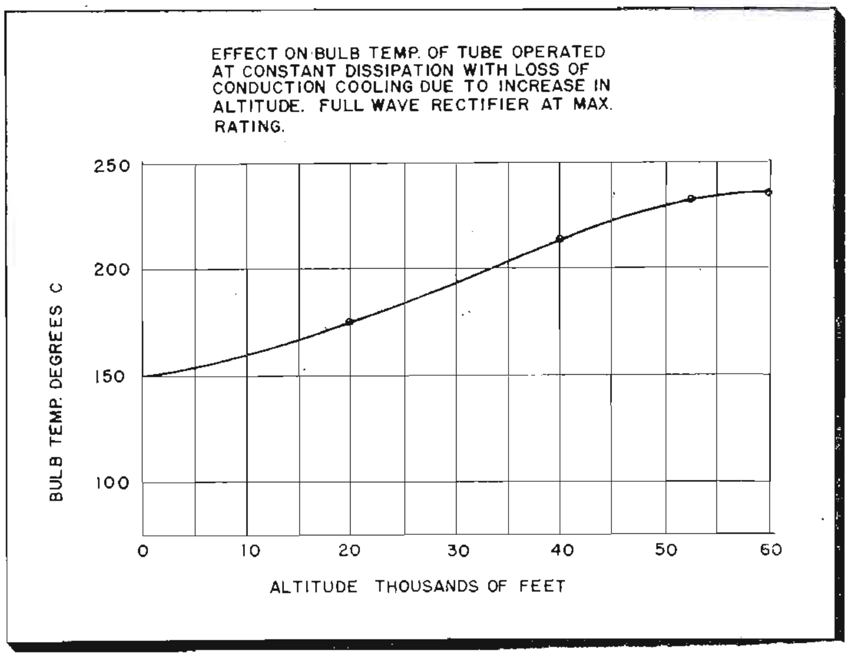


Fig. 5: Effect of vibration on tube life

Fig. 3: (l) Effect of bulb temperature variations on cathode temperature. Fig. 4: (r) Effect of high altitude on bulb temperature





Waveguides

Economic analysis of transmission line installation and operating expenses shows how low waveguide attenuation offsets high initial costs

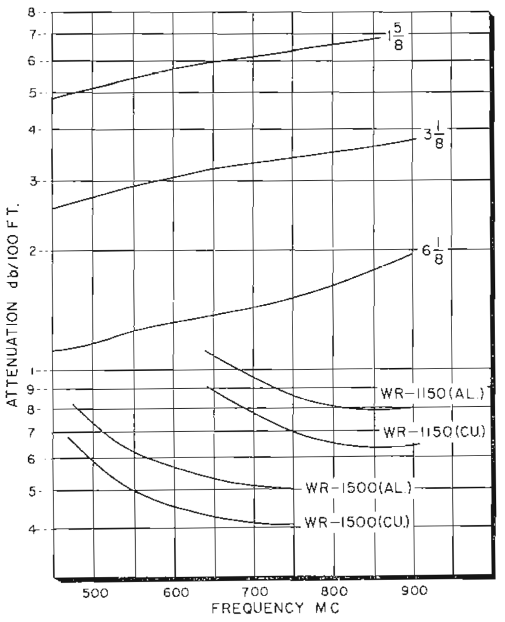


Fig. 1: Attenuation of aluminum and copper-clad steel waveguide, and coaxial lines

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Chicago 19, Ill.

THE use of waveguide for UHF-TV broadcast installations represents an approach to the transmission line problem that is not feasible for VHF-TV. This paper presents design considerations involved in waveguide installations, and compares waveguide and coaxial line on an economic basis.

The primary advantage of waveguide is that it offers a lower attenuation transmission line than is possible with coaxial line. In addition, since there is no inner conductor involved, any possibility of trouble from inner conductor connectors, etc., is eliminated. The absence of insulation inside the waveguide makes it unnecessary to pressurize the guide, which also simplifies operation and maintenance.

Initial Cost

The principal disadvantage of waveguide is that of higher initial cost. The larger size and therefore greater wind loading will require, in general, a more costly tower than would be required for coaxial line. Installation costs will, in most cases, be higher than for coaxial line.

From a basic design standpoint, either round or rectangular cross section waveguide might be considered as possible shapes. However, the rectangular guide is definitely preferred. The projected area, and therefore wind load, is less for a rectangular guide than for a round guide with the same cutoff frequency. The useful frequency range in rectangular guide is substantially greater than for round. For the rectangular shape, the frequency ratio of the first and second modes is two to one, and in round guide it is only 1.3 to 1. This means that five or six different sizes of round guide would be required to cover the UHF-TV band, while two sizes will accomplish the same coverage in rectangular guide. The polarization of the propagated wave tends to rotate irregularly in round guide, making it difficult to couple into and out of the guide. Almost the only advantage of the round guide is its lower attenuation. Present standards are set up to use rectangular guide in the dominant TE_{10} mode.

Small Range

While rectangular waveguide can be operated in the dominant mode over a two to one frequency range, its practical use is limited to a smaller range. The attenuation is quite high at frequencies close to the cutoff, and operation near this frequency is usually avoided. The RETMA has established standards on two sizes of guide for use in the UHF-TV spectrum. WR-1500, which measures 7½ x 15 in. inside dimensions, is designed to cover from 470-750 MC. WR-1150, which measures 5.75 x 11.5 in. inside dimensions, is designed to cover from 640-890 MC. In the range 640-750 MC, either size can be used, but the larger size has lower attenuation.

While waveguide in smaller sizes is fabricated by drawing or extrusion processes, these large sizes are beyond the capacity of such fabrication facilities, and it is necessary to manufacture these guides from sheet metal. Of the various metals available, aluminum and copper clad steel seem to be the best practical possibilities, and waveguides have been made out of both materials. Copper is, of course, also a possibility, but its low strength requires such a heavy sheet that it cannot compare on a cost basis. The use of copper clad steel combines the strength of steel and the good conductivity of copper. Since the primary reason for using waveguide at UHF-TV is to obtain low attenuation, copper clad steel is definitely preferred over aluminum, since its attenuation is about 80% that of aluminum.

This material is produced by welding together plates of copper and steel, and then rolling them to the desired size and thickness. In this manner the intrinsic high conductivity of copper is retained, and the copper is present on the conducting surface where it is needed for low attenuation. Fig. 1 shows the attenuation of waveguides fabricated of aluminum and copper clad steel, with coaxial line attenuations also included for comparison.

Tower Installation

Another advantage of copper clad steel is the simpler tower installation that can be used. Experiments indicate that the thermal coefficient of expansion of copper clad steel sheet is the same as that of steel alone. This means that when the wave guide is installed on a steel tower, it can be bolted rigidly to the tower without providing for differential thermal expansion. If aluminum is used, a spring hanger type of installation is required to accommodate this difference.

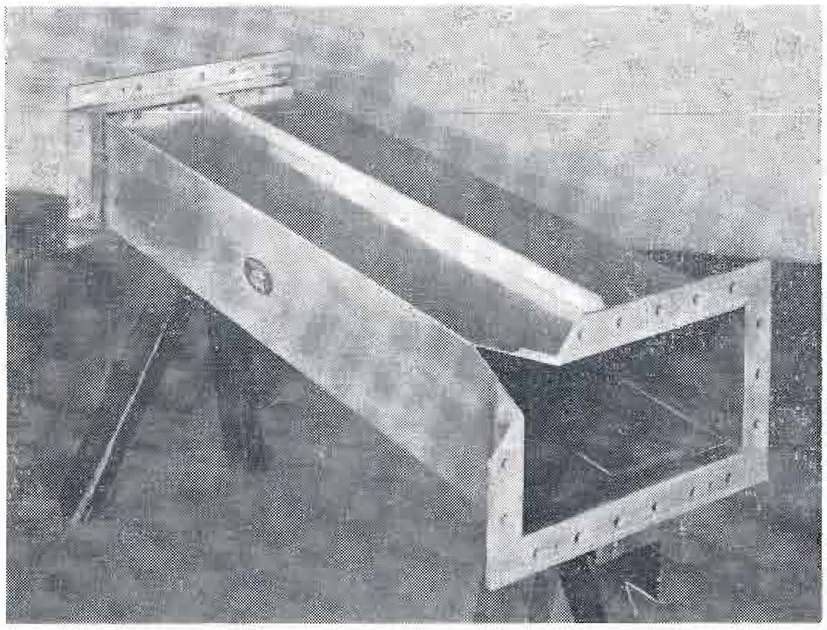
Fig. 2 is a photograph of a short piece of waveguide and shows one construction that may be used. It is made of copper clad steel sheet, with 0.050 in. of steel clad on both sides with 0.006 in. of copper. The copper

WAVEGUIDE VS. 6⅛ IN. COAXIAL LINE

TABLE I: Years to Balance Higher Initial Waveguide Cost Against Operating Savings

TV CHANNEL	250 Ft. Tower		500 Ft. Tower		1000 Ft. Tower	
	WR1150	WR1500	WR1150	WR1500	WR1150	WR7500
19 (500-506 MC)		2.4	—	3.0	—	5.8
49 (680-686 MC)	.4	1.4	.7	1.5	1.9	4.7
77 (848-854 MC)	.25	—	.4	—	1.2	—

for UHF Television



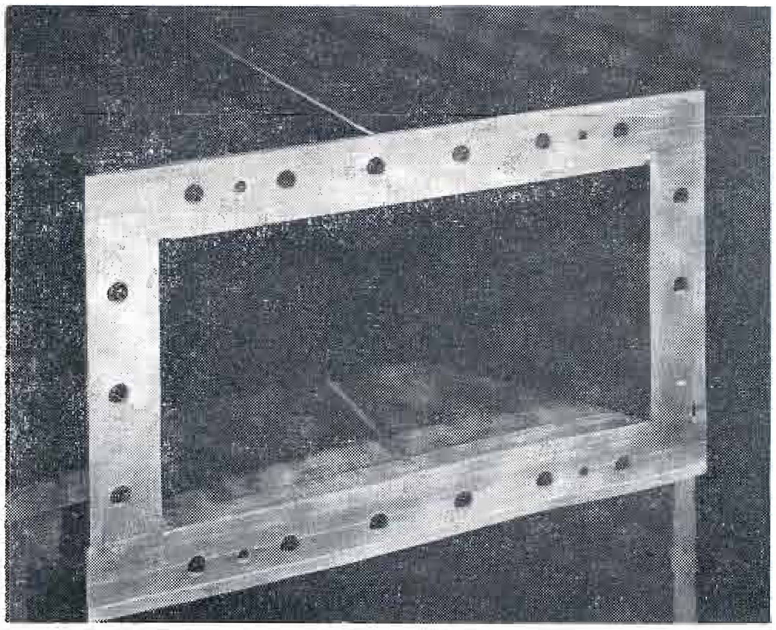


Fig. 2: (l) Waveguide section made from copper-clad steel sheet. Note spot-welded seam. Fig. 3: (r) Flange for connecting 10-ft. guide sections

clad steel sheets are bent to form two halves, and are joined by spot welding in the center of the long dimension of the waveguide cross section. The joint is located in this position because at this point in the waveguide no current flows across the joint, eliminating the necessity for a continuously soldered or welded good conductivity joint. The waveguide is normally fabricated in 10 ft. long flanged lengths. This length is limited at the present time by the length in which sheets are available. Fig. 3 is a photograph of the type of flange that is used for joining ten foot sections. These flanges are being standardized dimensionally by the RETMA, so that interchangeability between waveguide supplied by all manufacturers will be assured.

Few Fittings Needed

Relatively few fittings are required for a waveguide installation, since the connections at the ends are usually made in coaxial line. Transitions to coaxial line, elbows in both planes, and mounting clamps will be the only fittings required for most installations. Fig. 4 shows a transition from WR-1150 waveguide to 3⅛ coaxial line. Fig. 5 shows a mounting hanger for supporting the waveguide on a tower. It attaches to the seam on the waveguide rather than to the flange, which makes attachment to the tower much easier and more flexible.

Since the waveguide is not pressurized, some breathing and accumulation of moisture within the guide is inevitable. This can be easily taken care of by drilling small drain holes in the guide at the lowest point (or points) in the system, so that any moisture that collects will drain out.

Perhaps the principal technical problem in connection with copper clad steel as a material is the corrosion problem. It must be emphasized that the corrosion resistance of this material cannot be compared to that of a copper plated surface, which provides inherently poor corrosion protection primarily because of its porosity.

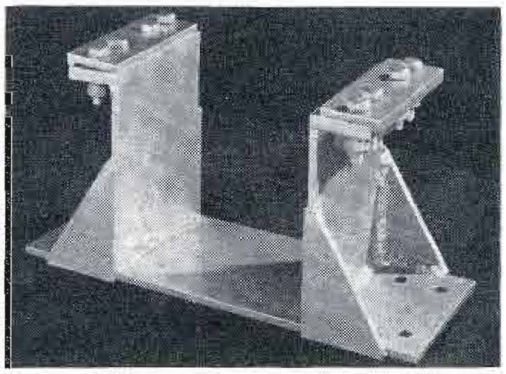


Fig. 4: Coax-to-waveguide transition

Since the copper on a clad sheet starts out as a relatively thick rolled sheet of copper, it does not exhibit porosity, and if the cladding operation is properly controlled the continuity of copper is excellent. Copper thickness used at the present time for waveguides is 0.006 in. Clad panels with 0.003 in. of copper have been exposed to the outside atmosphere in Chicago for approximately one year without any indication of corrosion.

The edges of the sheets are, of course, subject to corrosion and must be protected. Where they occur outside the electrically operative part of the guide they may be painted. Inside edges are currently protected by tinning (soft solder). The entire outside of the guide can be painted when the tower is painted, thus providing additional protection on the surfaces that are subject to the worst corrosion conditions.

The only commercial justification for the use of waveguide is on economic grounds. There are, of course, many ways to make an economic analysis and the results almost always depend on individual conditions. The following analysis has been prepared to show in a general way the justification for the use of waveguide.

Basis for Comparison

The basis used was to compare waveguide and coaxial line on an "equal radiated power" basis. Since the attenuation of waveguide is lower than that of coaxial line, less r-f power output from the transmitter is required to produce the same radiated power. This results in operating savings which will balance out the higher initial costs of waveguide. These higher costs include not only the waveguide, hangers, and fittings, but also the extra costs of a heavier tower and more expensive installation. The operating savings were based on a transmitter of 10 to 12 KW rating, and include savings in transmitter tubes and power costs on the basis of a 12 hour daily operating schedule.

(*Continued on page* 170)

Recent Electronic Developments at

MICROWAVE FREQUENCY STANDARD SERVICE

IN an effort to keep pace with the growing utilization of an ever expanding r-f spectrum, NBS makes available to science and industry accurate standards of frequency measurement. Research and development of frequency standards in the microwave frequency spectrum is under the direction of Dr. Harold Lyons and L. J. Rueger. The Microwave Frequency Standards Laboratory is equipped to operate between 300 and 40,000 MC with completely standardized equipment, and up to 75,000 MC with instruments currently in the final stages of development. In addition to the broad research program in microwave principles and techniques, the laboratory calibrates the secondary microwave frequency standards used in science and industry.

Frequency meters sent to the Bureau are calibrated, when possible, under normal operating conditions. For instance, if the meter has a build-in detector and indicator, sufficient power is used to operate the complete indicating system. Or, if the meter can be employed either as a transmission or a reaction device, the calibration includes both methods, and checks are made for any existing discrepancies between the two. The ambient room temperature of the calibration laboratory is maintained at 23° ±2° C, and the relative humidity to 50 percent ±2 percent. Meters are permitted to reach equilibrium with the room conditions before a calibration is made.

In the calibration procedure, the standard frequencies are applied to a crystal diode mixer. The desired signal is selected and all others are rejected by a tunable transmission filter, which has been previously

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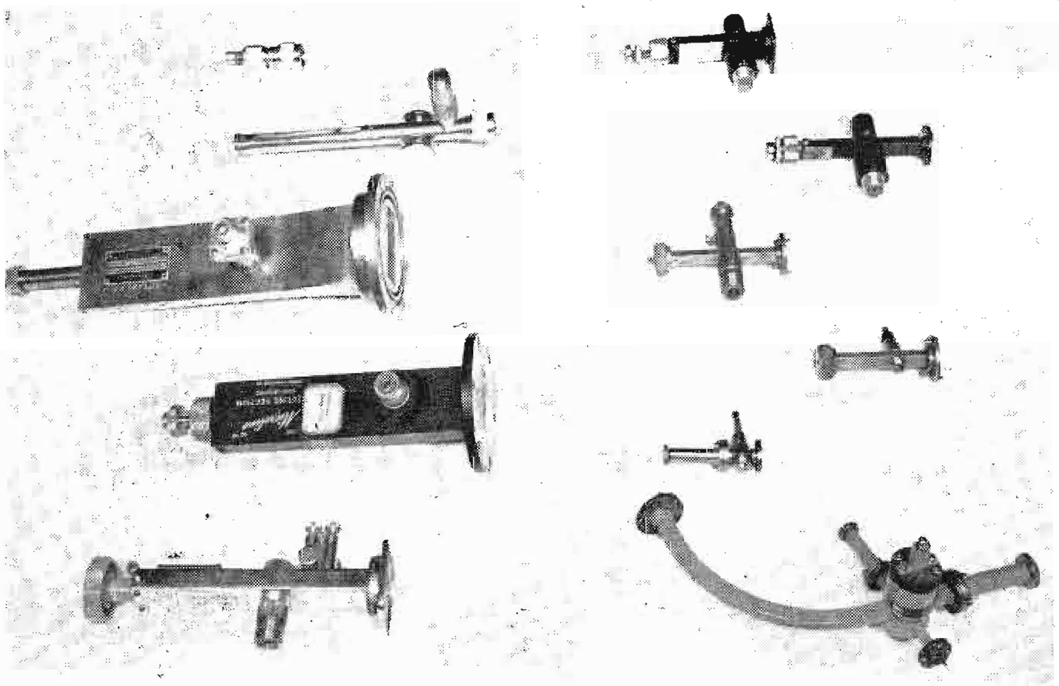
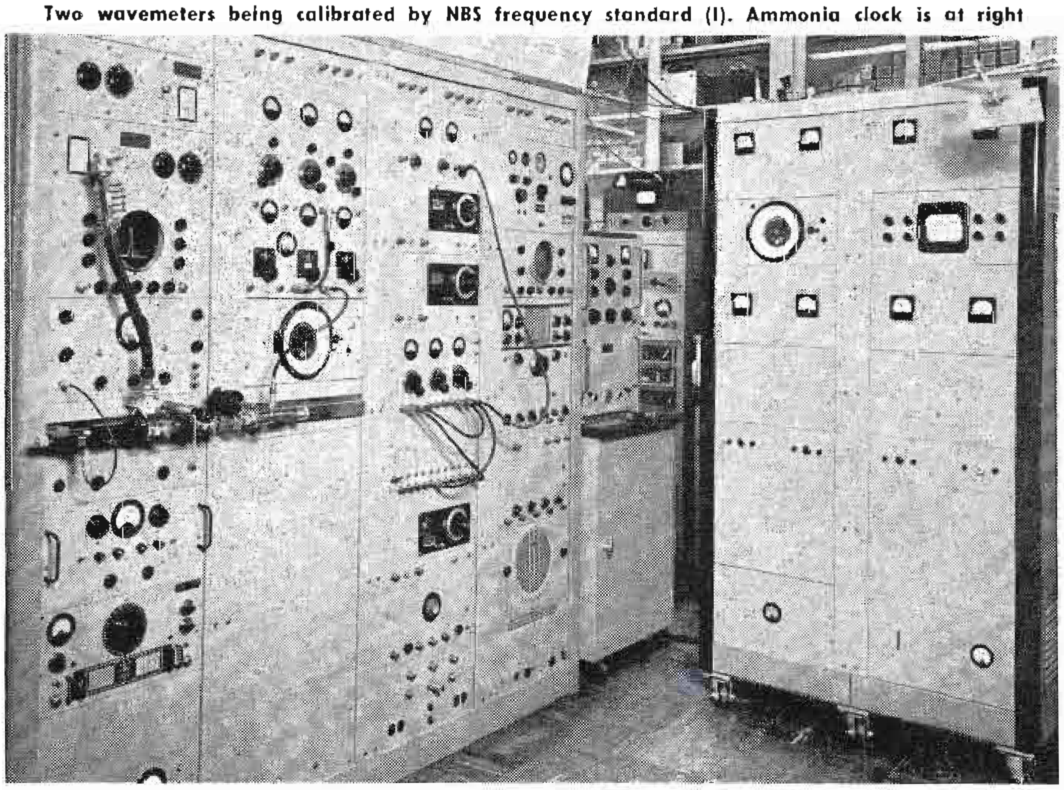
Harmonic generators covering 300 to 10,000 MC (u-l to l-l) and 10,000 to 75,000 MC (u-r to l-r)



Two wavemeters being calibrated by NBS frequency standard (l). Ammonia clock is at right



AUTOMATIC COMPUTER

SWAC—the National Bureau of Standards Western Automatic Computer—is now being operated 24 hours a day, five days a week to solve a wide range of complex problems. SWAC is a general-purpose digital computer constructed by NBS in 1950 under the sponsorship of the Wright Air Development Center, and contains 2600 tubes and 3700 crystal diodes. The first of the high-speed electronic computers to be completed with the very fast Williams tube (cathode-ray tube) memory, SWAC operates at a rate of 16,000 additions or 2600 multiplications per second.

Recently the scope and complexity of the problems which the machine can handle have been greatly extended through the installation and successful operation of a magnetic drum auxiliary memory. The new memory holds 16 times as much mathematical information as the CRT memory with which it will be used.

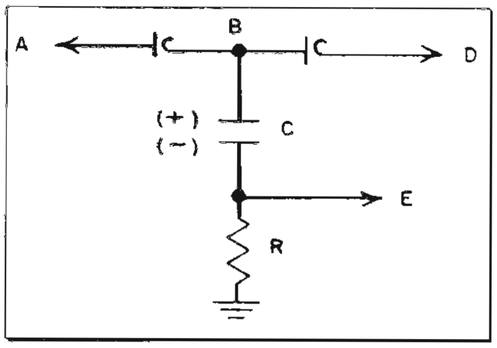
SWAC's high speed results from its special Williams tube memory and its parallel mode of operation. The memory unit consists of a bank of cathode-ray tubes which store information as bright spots of charge. The unit is operated in parallel, that is, all the digits of a number are transferred in or out of the memory simultaneously, thus greatly reducing the time required for transfer of information. In serial machines, such as those using acoustic-delay-line memories, numbers and instructions are represented by trains of electrical pulses. But in

(*Continued on page* 141)

the National Bureau of Standards

DIODE-CAPACITOR MEMORY FOR HIGH-SPEED COMPUTERS

A. W. Holt of the Electronic Computers Laboratory, has recently completed prototype memory based on the idea of utilizing diodes and capacitors as the basic storage units. It more than matches the speed of the arithmetic unit used presently in SEAC and should at the same time, because of its simplicity, be more reliable than other memories



Storage element in diode-capacitor memory

now in use. The most difficult part of the basic problem of high-speed access was overcome by the development of a selector matrix switch using diodes and transformers. The test system was recently connected to SEAC, and a continuous checking program was run on it for 12 hours without a single error.

The basic circuit for the storage element consists of two diodes in series, with one side of a capacitor tied to their mid-point, and the other side grounded through a resistor. Point "E" is used for both reading and writing, while the two diodes are used as a "squeezer" to connect the capacitor to the read-write circuits. During holding, both diodes are biased in their back direction. For example, the anode of one diode might be held at —4 volts while the cathode of the other is held at +4 volts. Then, if the capacitor has a charge of, say, 2 volts, both diodes will be biased in their back direction, and only small currents will flow into or out of the capacitor.

When the ends of the diodes are both forced to ground potential ("squeezed"), one diode or the other will conduct, and a voltage will appear across the resistor. If the capacitor has been charged with 2 volts of such polarity as to make its lower terminal more negative than its upper terminal, there will appear at the output E a pulse of −2 volts, which dies out with the time constant RC. This negative pulse is recognized by the reading circuits at the output as the binary digit "zero." If the polarity on the capacitor had been in the opposite direction, the squeeze would have produced a positive pulse which would be recognized as the binary digit "one." Thus, the content of the storage element has been read; but in the process it has been at least partially discharged, and the information has been lost from the storage element. The information must be rewritten to continue the storage beyond the reading operation.

In order to write (or rewrite) information it is only necessary to force the point E to the desired state and hold it there until the squeeze is over. While the ends of the diodes are at zero voltage, assume that E is forced to +2 volts and held there until the diodes are returned to their

(Continued on page 138)

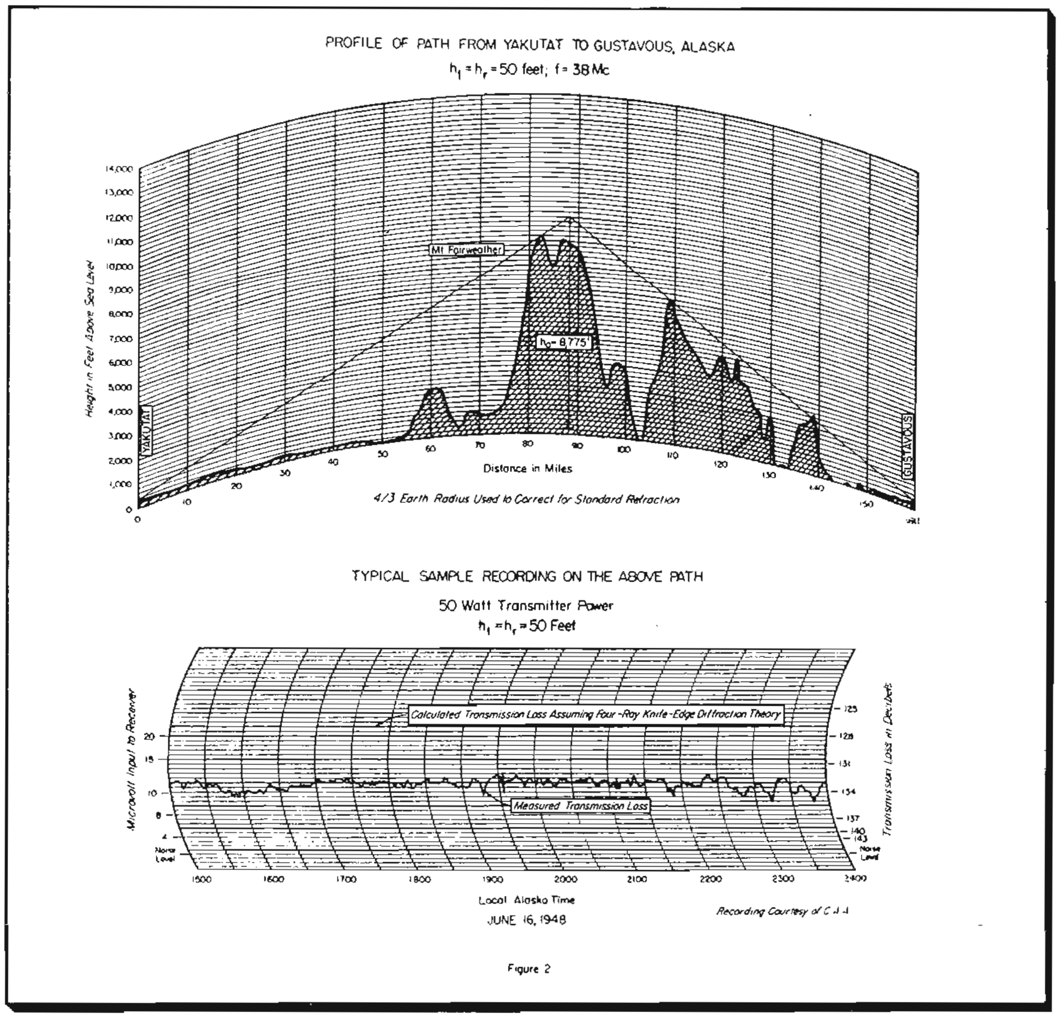
See page 86 for more reports of recent developments at the National Bureau of Standards

"OBSTACLE-GAIN" VHF TRANSMISSION

Recent experiments with long-range VHF transmission in mountainous regions have demonstrated the possibility of utilizing knife-edge obstacles as a means for increasing the received signal energy of TV, FM, and military communications. Analyses of the experimental data and interviews with scientists and engineers in the field were conducted jointly by the U. S. Army Signal Corps, NBS and RCA. Indications are that the disadvantages previously attributed to transmission of very high frequencies (30 to 100 MC) among high mountain ridges can actually become powerful aids for reducing both transmission loss and tropospheric fading. The results of these obstacle-gain experiments may have a

(Continued on page 146)

Profile (top) of VHF transmission path. Experiment demonstrates how high mountain ridges may be used to increase received signal strength. Recording (below) shows actual loss



SEMICONDUCTING INTERMETALLIC COMPOUNDS

Investigations into the fundamental properties of semiconductors have revealed that certain intermetallic compounds show promise of extended use in solid state electronic devices. Current research, under the direction of R. G. Breckenridge of the Solid State Physics Laboratory is concerned principally with the conductivity and the Hall effect of such metal compounds as indium antimony (InSb) and aluminum antimony (AlSb). Of immediate importance is the fact that these combinations may have equal or greater utility than the germanium and silicon semiconductors presently in large demand. More extensive investigations are expected to disclose many useful and interesting characteristics of these hitherto relatively unexplored materials.

The current research program has involved an investigation of the Hall effect and the conductivity of several such semiconducting materials. Related phenomena, such as optical absorption spectra, photoconductivity, and rectification effects, are also under observation. All of the studies thus far have been performed with polycrystalline samples; but when methods of growing single crystals have been successful, each experiment will be repeated on these crystals.

High charge carrier mobility is a fundamental property required for transistor action. In a point contact transistor the emitter injects "holes" into the semiconductor. These holes migrate under the influence of the applied electric field to the collector where their presence influences the flow of electrons from the collector through to the base electrode. The ability of the transistor to follow high frequencies depends on how fast the holes can travel from the emitter to collector; the shorter the time required, the higher the frequency. In a typical sample of high grade germanium, the mobility is about 3000 cm^2/volt sec. For ordinary-size electrodes and spacings this restricts the highest frequency to about 10 or 20 MC. By making the contact points very small and by putting them very close together,

The samples of indium antimony investigated by NBS have not been sufficiently pure to give transistor action, but their mobility (20,000 cm^2/volt sec.) is about seven times that of germanium. With sufficiently pure samples, transistor action should be possible at much higher frequencies and at higher power levels. The mobilities in the other compounds studied (GaSb, AlSb, CdSb), while high, are apparently not as high as in InSb and may not function as well at high frequencies.

From investigations of the temperature variation of Hall effect and conductivity, it was found that the activation energy of indium antimony is about 0.40 e.v. This value is too low to allow transistor action at elevated temperatures. Gallium antimony, on the other hand, has an activation energy of about 0.86 e.v. —somewhat greater than germanium; and aluminum antimony appears to have an activation energy greater than 1 e.v.—slightly larger than the energy of silicon. It is assumed that from the variety of intermetallic compounds available it will be possible to find suitable

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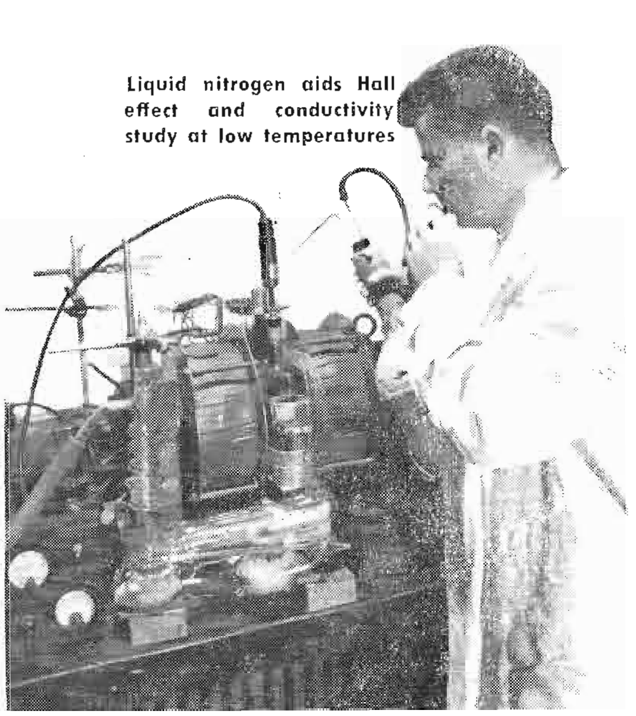


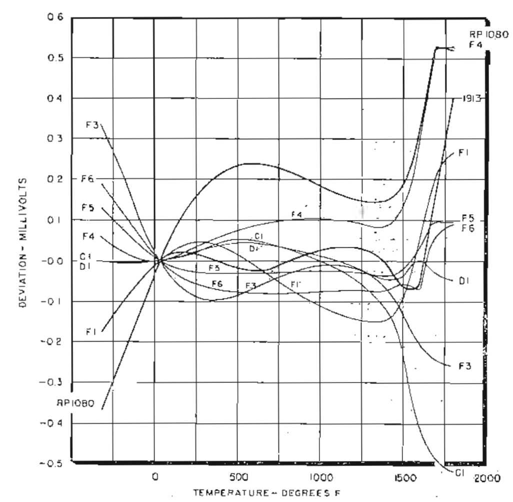
Liquid nitrogen aids Hall effect and conductivity study at low temperatures

IRON-CONSTANTAN THERMOCOUPLE TABLES

New reference tables for iron-constantan thermocouples, constitute an important step toward uniformity in this field. Covering a very broad range—from −310 to +1600 F—the new tables correspond more closely to the properties of commercially available thermocouples than do any of the other iron-constantan reference tables currently in use. The NBS tables are based on an investigation carried out by R. J. Corruccini, Henry Shenker, and other members of the Bureau staff at the request of the Scientific Apparatus Makers of America. They have been recommended by the SAMA for adoption as a tentative standard.

Each member firm of the SAMA that supplies iron-constantan thermocouples was invited to submit sample thermocouples for investigation at NBS. These samples were to be of commercial materials selected to match closely the 1913 table over the range from 32° to 1400° F. Eight different lots of matched iron and constantan wires of size approximately No. 8 AWG were submitted. Information received from some of the suppliers indicated that the iron samples came from at least four different basic sources of ingot iron.

The thermal emf's of the various wires were measured in the NBS temperature measurements laboratory from −319.5° to +1800° F. From these data, the corresponding thermal emf's for the iron-constantan thermocouples were computed.



Deviations of old tables and various thermocouples from relationships in the new tables

Chemical and spectrographic analysis of the iron samples and hardness determinations were also made.

From 32° to 1800° F, the wires were calibrated in a tubular electric furnace. For convenience, the iron wires were calibrated against a standard iron wire, and the constantan wires against a standard constantan wire. The standard iron and constantan wires had previously been calibrated against Pt 27, the NBS platinum thermoelectric standard, and they were rechecked at frequent intervals during each run against the platinum element of the platinum versus platinum-10 percent rhodium thermocouple used to measure the temperature. Because of the relative instability of the iron and constantan at temperatures above 1400° F, measurements in this range were made against a platinum standard only.

Unbalanced RLC Networks

Enlightening analysis of circuit transfer functions results in lossless coupling network containing only one resistance and one real transformer

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FOR many practical applications like coupling a tube to its resistive load or to another tube, or constructing filters of all types, it is necessary to be able to realize a given transfer function in a suitable form of network. One highly desirable form is that of an unbalanced network (that is, one with a common input and output ground terminal) composed of lossless elements terminated in a resistance.

In a previous paper[1] a solution was given to the problem of realizing a given transfer admittance by a Darlington network, such a network being defined as one possessing lossless elements plus only one resistance. We demonstrate in this paper an alternate solution to the Darlington problem by realizing a transfer function as an unbalanced lossless network terminated in a resistance. This procedure is more general in that the transfer function is not restricted to the dimensions of an admittance but may also be a transfer voltage ratio or a transfer impedance. The final network is achieved through the intermediate step of designing a lattice whose arms are canonic Foster two-element kind networks containing the same poles. No mutual inductance is needed for realizing the lattice. In many cases the lattice can be reduced to an unbalanced network without the addition of mutual inductance; it can always be reduced by the use of one real transformer, that is, a transformer with finite magnetizing inductance and a coupling coefficient smaller than one.

This paper
was presented at
1953 WESCON
Western Electronic Show & Convention
August 19-21, 1953
San Francisco, Calif.

It is well known that it is impossible to realize a minimum phase transfer function with zeros off the j-axis by means of a lossless coupling network terminated in a single resistance.[2] Therefore for realization as a lattice by the method of this paper it is necessary that the given function have an even or odd numerator. However, to guarantee reduction to an unbalanced form, the numerator must be an even polynomial for a transfer admittance or transfer voltage ratio and an odd polynominal for a transfer impedance. Atttention is focused on realization of the unbalanced network since it includes the steps for lattice realization. Furthermore, only the procedures for the transfer admittance and the transfer impedance need be demonstrated: it is clear that because of the resistance termination the problem of achieving a transfer voltage ratio is almost identical with that of the transfer admittance. The general formulas upon which we base our discussion are given in a previous paper[3] on another method of RLC synthesis; they are also given in the Bower-Ordung method of RC synthesis.[4] In both cases they are applied to different problems. A detailed discussion is therefore not required but for purposes of clarity and definition of symbols we shall restate the necessary development and formulas in this paper.

The method for lattice synthesis will be given first and then the general reduction procedure will be demonstrated.

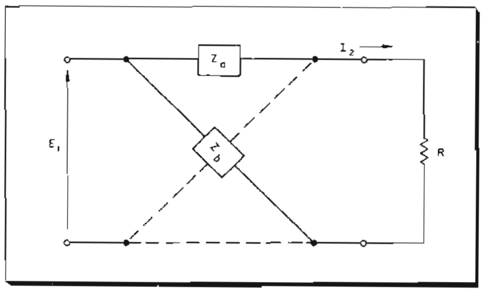


Fig. 1: Lossless lattice terminated in R

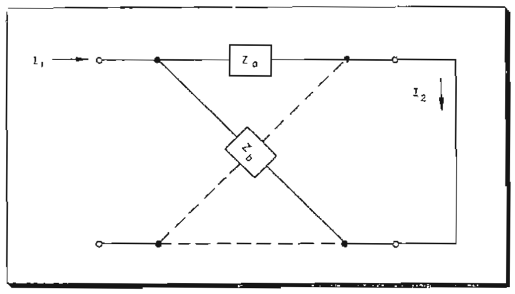


Fig. 2: Short-circuited lattice; $K = I_2/I_1$

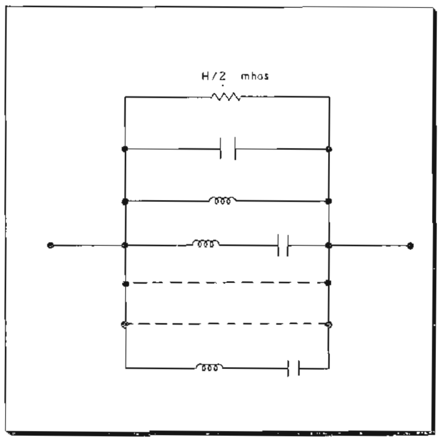


Fig. 3: (l) Form of arms in short-circuited lattice.

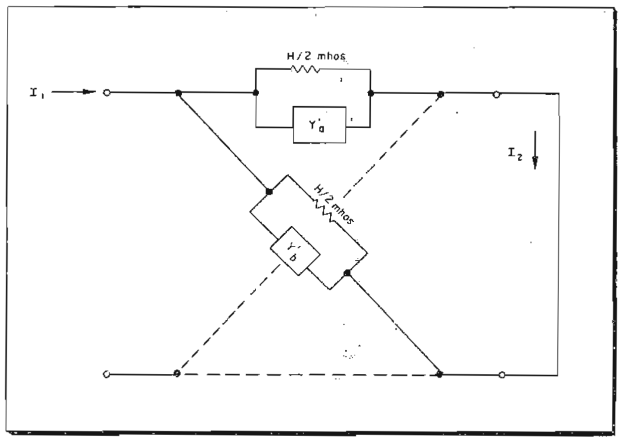


Fig. 4: (r) Lattice where $I_2/I_1 = p/Hq$

Synthesis Procedure

We are given a quotient of polynomials p(s)/q(s), where p is even and of degree equal to or less than that of q, and q is completely general, i.e., is restricted only in that it must be a Hurwitz polynomial. We wish to realize the given function within a multiplicative constant as the transfer admittance Y_{12} of the resistance-terminated lattice shown in Fig. 1. First we realize the short-circuited lattice shown in Fig. 2; then by lattice transformations[3] we obtain the resistance-terminated lattice characterized by Y_{12}.

We let the ratio of the currents in Fig. 2 be expressed as

$$K = \frac{I_2}{I_1} = \frac{p}{Hq} = \frac{m_1}{H\,(m_2 + n_2)}, \quad (1)$$

where H is a positive constant, m_1 is the even numerator, and m_2 and n_2 are respectively the even and odd parts of the denominator. Since for a short-circuited lattice we know that:

$$K = \frac{I_2}{I_1} = \frac{y_{12}}{y_{11}} = \frac{Y_b - Y_a}{Y_b + Y_a} \quad (2)$$

and that the short-circuit transfer admittance of y_{12} of a lossless network cannot be given by the ratio of two even or two odd polynomials, we divide numerator and denominator of Eq. 1 by n_2 to obtain

$$K = \frac{m_1/n_2}{H\,(1 + m_2/n_2)}, \qquad (3)$$

which, when equated with Eq. 2, yields

$$K = \frac{m_1/n_2}{H\,(1 + m_2/n_2)} = \frac{Y_b - Y_a}{Y_b + Y_a}. \qquad (4)$$

It is now necessary to show how the numerator and denominator that have been derived from the given rational function may be identified with the lattice arms so that Eq. 4 is satisfied.

We consider Y_b and Y_a and also m_1/m_2 and m_2/n_2 as expanded in partial fractions. The residues of m_1/n_2, which we will designate by $k_u^{(n)}$, are all real but may be positive or negative; those of m_2/n_2, moreover, are real and positive, since the ratio of the even and odd parts of a Hurwitz polynomial forms a positive real lossless function.[5] Thus the partial fraction expansion of the denominator may be written as

$$H\,(1 + m_2/n_2) = H\,\Big(k_0^{(d)} + k_1^{(d)} s + \frac{k_2^{(d)}}{s} + \frac{k_3^{(d)}}{s - s_3} + \frac{k_4^{(d)}}{s - s_4} + \frac{k_5^{(d)}}{s - s_5} + \frac{k_6^{(d)}}{s - s_6} + \ldots\Big)$$
$$= H\,\Big(k_0^{(d)} + k_1^{(d)} s + \frac{k_2^{(d)}}{s} + \frac{k_3^{(d)}}{s - s_3} + \frac{k_3^{(d)}}{s - \bar{s}_3} + \frac{k_5^{(d)}}{s - s_5} + \frac{k_5^{(d)}}{s - \bar{s}_5} + \ldots\Big), \qquad (5)$$

where $k_0^{(d)} = 1$ and all the other k's are real and non-negative. It is clear that $k_1^{(d)} = 0$, if the degree of q, the denominator of the given quotient of polynomials, is odd. It is pointed out, furthermore, because of its importance in the reduction of the lattice to an unbalanced network, that $k_2^{(d)}$ is always greater than zero, that is, the pole at the origin is always present.

If we now equate the residues of like terms for the numerator and denominator of Eq. 4, we obtain

$$\left.\begin{array}{l} k_\mu^{(b)} - k_\mu^{(a)} = k_\mu^{(n)} \\ k_\mu^{(b)} + k_\mu^{(a)} = Hk_\mu^{(d)} \end{array}\right\} \cdot \quad (\mu = 0, 1, 2, \ldots r, \text{ where r is the degree of q}) \qquad (6)$$

This set of two simultaneous equations may be solved simply for the unknown residues of the lattice arms, $k_\mu^{(a)}$ and $k_\mu^{(b)}$. The solution is obtained at sight as

$$\left.\begin{array}{l} k_\mu^{(a)} = \frac{1}{2}\,(Hk_\mu^{(d)} - k_\mu^{(n)}) \\ k_\mu^{(b)} = \frac{1}{2}\,(Hk_\mu^{(d)} + k_\mu^{(n)}) \end{array}\right\} . \qquad (7)$$

For $\mu = 0$ we see from the form of m_1/n_2 that $k_0^{(n)} = 0$ so that it is always true that $k_0^{(a)} = k_0^{(b)} = H/2$. In order for $(Y_a - H/2)$ and $(Y_b - H/2)$ to be positive real reactance functions, it is necessary and sufficient that their respective residues $k_\mu^{(a)}$ and $k_\mu^{(b)}$ for $\mu \neq 0$ be non-negative. Applying this condition to each of the solutions in Eq. 7 and also making use of the fact that $k_\mu^{(d)}$ is never negative, we obtain as the condition to me satisfied,

$$-1 \leq \frac{k_\mu^{(n)}}{Hk_\mu^{(d)}} \leq 1. \qquad (8)$$

The positive constant H is within our control; by choosing it sufficiently large, the above condition can be met for all values of μ. The lattice arms are then given by an expansion of the the form

$$Y = H/2 + k_1 s + k_2/s + k_3/(s - s_3) + k_3/(s - \bar{s}_3) + \ldots \qquad (9)$$

and may be realized by inspection as a network of the form shown in Fig. 3. in Fig. 4 is shown the type of short-circuited lattice achieved, where Y'_a and Y'_b are lossless functions.

To convert to a resistance-terminated lattice, we first derive an equivalent lattice by removing the total conductance from each arm and inserting it as a shunt branch in parallel with each of the input and output terminal pairs; then we replace the current scource with its shunt conductance by an equivalent voltage source plus a series resistance; finally the application of the reciprocity theorem gives a lattice terminated in a conductance of H/2 mhos for which [3,6]

$$Y_{12} = I_2/E_1 = (1/2)\,p/q. \qquad (10)$$

The sequence of steps is shown in Fig. 5.

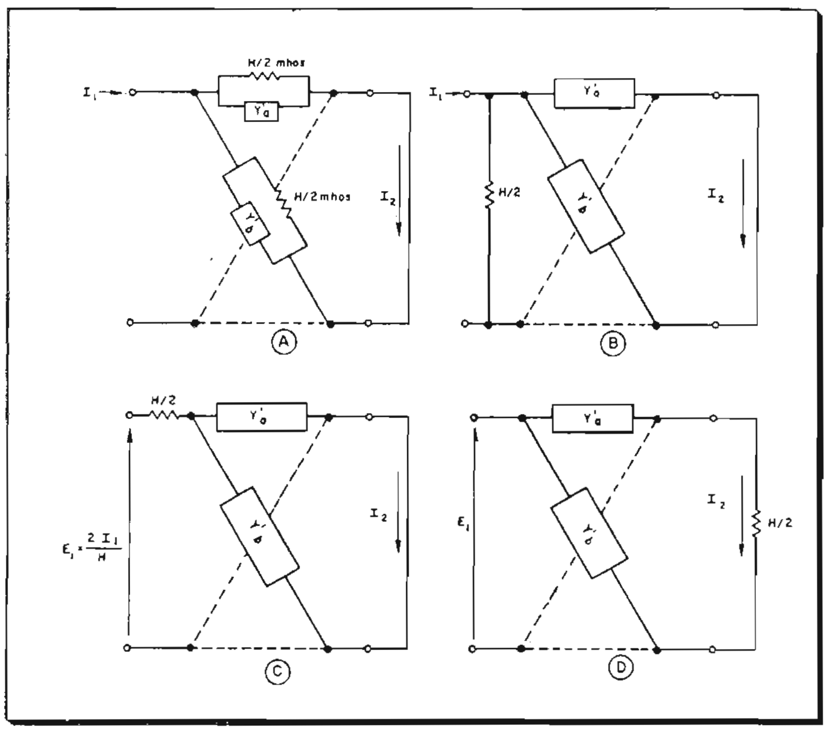


Fig. 5: (1) Steps in conversion of short-circuited lattice to resistance-terminated lattice

Lattice Synthesis Summary

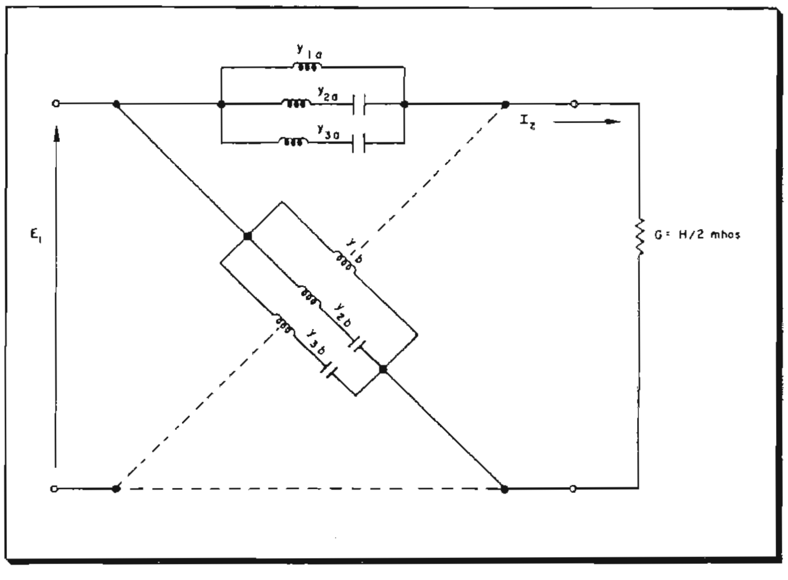
The lattice synthesis procedure is now complete and may be summarized as follows:

1. Divide the numerator and denominator of the given transfer admittance by the odd part of the denominator. (We are assuming an even numerator: of course, for p an odd polynomial we divide by the even part of the denominator.)

2. Expand m_1/n_2 and m_2/n_2 in partial fractions.

3. For each pole satisfy the appropriate part of Eq. 8 with the equals sign; that is, for $k_\mu^{(n)}$ negative choose a value of H that satisfies $k_\mu^{(n)}/Hk_\mu^{(d)} = -1$; and for $k_\mu^{(n)}$ positive we satisfy the condition on

Fig. 6: Lossless lattice network



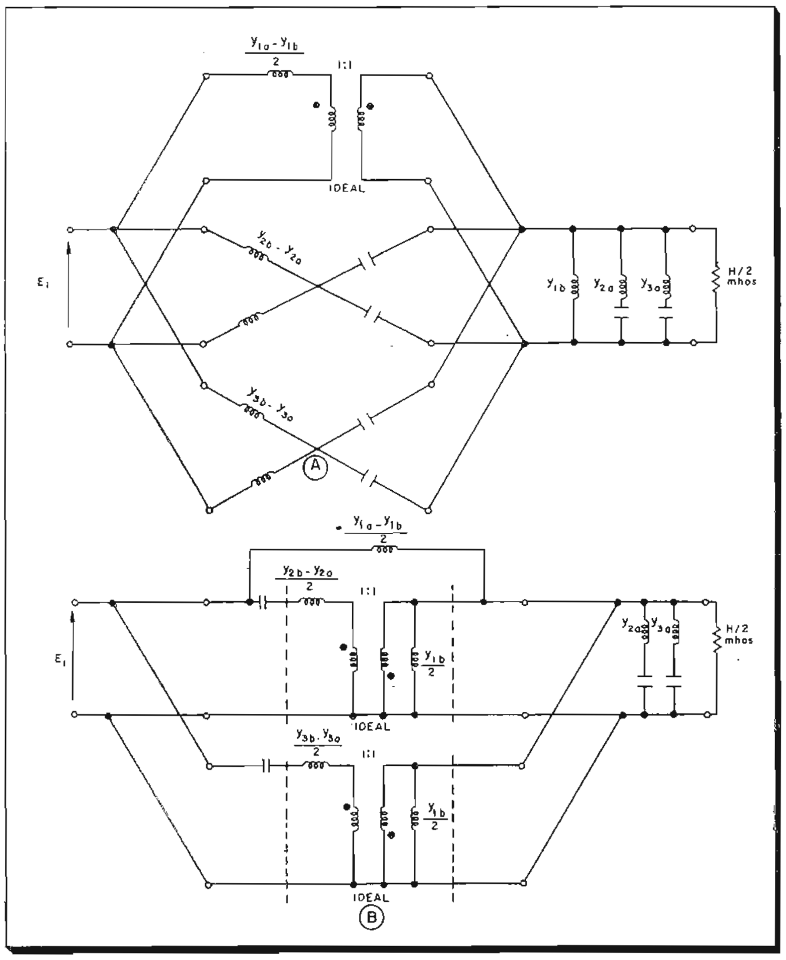


Fig. 7: Lattice reduction to unbalanced form, one real transformer

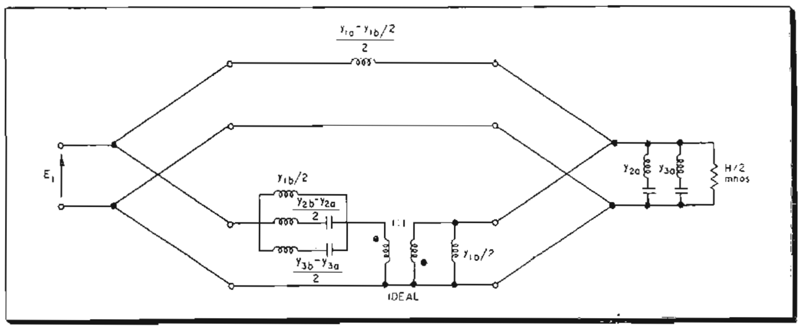


Fig. 8: Fig. 6 lattice divided into only two four-terminal networks

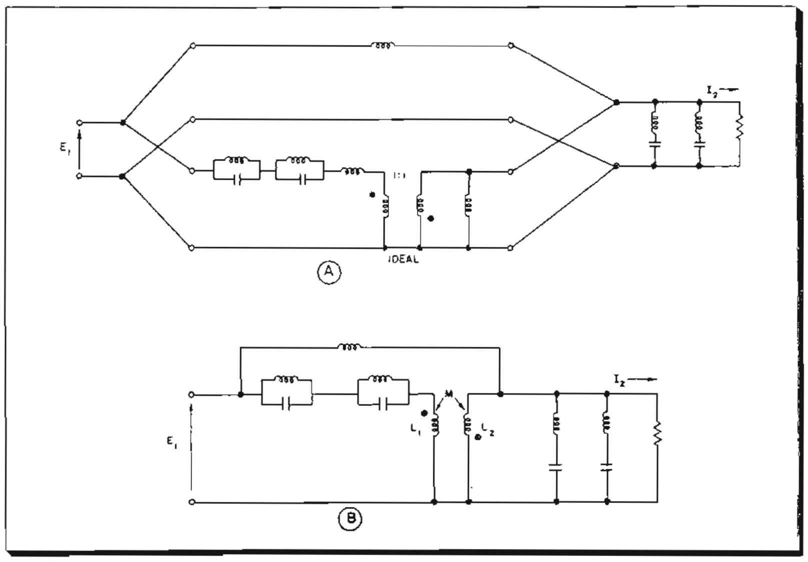


Fig. 9: Obtaining unbalanced network with one real transformer

the +1 with the equals sign. Tabulate all the H values. For the conjugate poles on the j-axis the residues are equal, i.e.,

$$k_\mu = k_\mu + 1 \text{ for } \mu \text{ odd and } \mu \geqq 3.$$

4. Choose a value of H greater than the largest value of H obtained in step 3. This guarantees the satisfaction of Eq. 8 with the inequality signs. (In some cases if we wish to save same elements we can let H equal the largest value: this makes the residue zero in one pole for one of the arms.)

5. Using Eq. 7 find all the residues of the lattice arms, and realize the arms in the Foster manner.

6. Convert the short-circuited lattice into one terminated in a conductance of H/2 mhos and possessing pure reactance arms.

Transfer Impedance

The procedure is analogous to the one for the transfer admittance with a few minor changes that are pointed out below.

In order for reduction of the lattice to be possible in all cases the numerator must be an odd polynomial. We first realize the transfer voltage ratio

$$K' = E_2/E_1 = z_{12}/z_{11} \qquad (11)$$

for the open-circuited lattice and then by lattice conversions obtain a lattice terminated in a resistance of H/2 ohms for which

$$Z_{12} = E_2/I_1 = (1/2)\, p/q. \quad (12)$$

In addition, however, we now realize the lattice arms by a partial fraction expansion of the lossless admittances; that is, we have the extra step of combining the partial fraction expansions of $(Z_a - H/2)$ and of $(Z_b - H/2)$, inverting to the admittance forms, and then expanding these admittances in partial fractions. It is pointed out that the admittances will always have a pole at the origin; the resulting shunt inductance will be used in the reduction to an unbalanced network. Except for this pole at the origin, like poles will not be present in the admittances of the lattice series and cross arms.

Reduction of Lattices

To demonstrate the lattice reduction we will consider the transfer admittance, a similar discussion holding for the transfer impedance. Because of its usefulness in some problems, we first discuss a procedure that requires the use of more than one real transformer. Then we consider the more significant method that uses only one real transformer.

The general form of network obtained has arms composed of parallel branches of series LC structures, plus one pure inductance branch and one pure capacitance branch. As pointed out previously there is always a pole at the origin so that a parallel inductance branch is always present. It has also been noted that the pure capacitance branch is present when the degree of q is even. This capacitance, part of which can always be removed from the lattice arms by a lattice transformation, is often useful in the practical instrumentation of the circuit, since it may provide for stray input or output capacitances or tube capacitances.

Three Branch Lattice

For convenience but without loss of generality we use as an illustration a lattice with three branches in each of its arms. The lattice is shown in Fig. 6, where like numerical subscripts designate like poles. Assume that the residues in y_{2b} and y_{3b} are greater than those in y_{2a} and y_{3a}, respectively, but the residue in y_{1a} is greater than that in y_{1b}. By the methods of transforming to equivalent lattices,[3,6] we may remove y_{1b}, y_{2a}, and y_{3a} from each arm, and break the ladder into a group of parallel ladders, as shown in Fig. 7(a). Then by a rotation of the output terminals of the middle and bottom lattices, as in Fig. 7 (b), we obtain an unbalanced form where each of the two sets of elements within the broken lines represents a real transformer,[7] that is, a transformer with a coupling coefficient less than one and finite magnetizing inductance.

Inspection of Fig. 7 (b) shows that

(Continued on page 128)

CUES for BROADCASTERS

Practical ways of improving station operation and efficiency

Flexible Installation for Tape Recorder

LAWRENCE L. PRADO, JR., Chief Engineer, WPEP, Taunton, Mass.

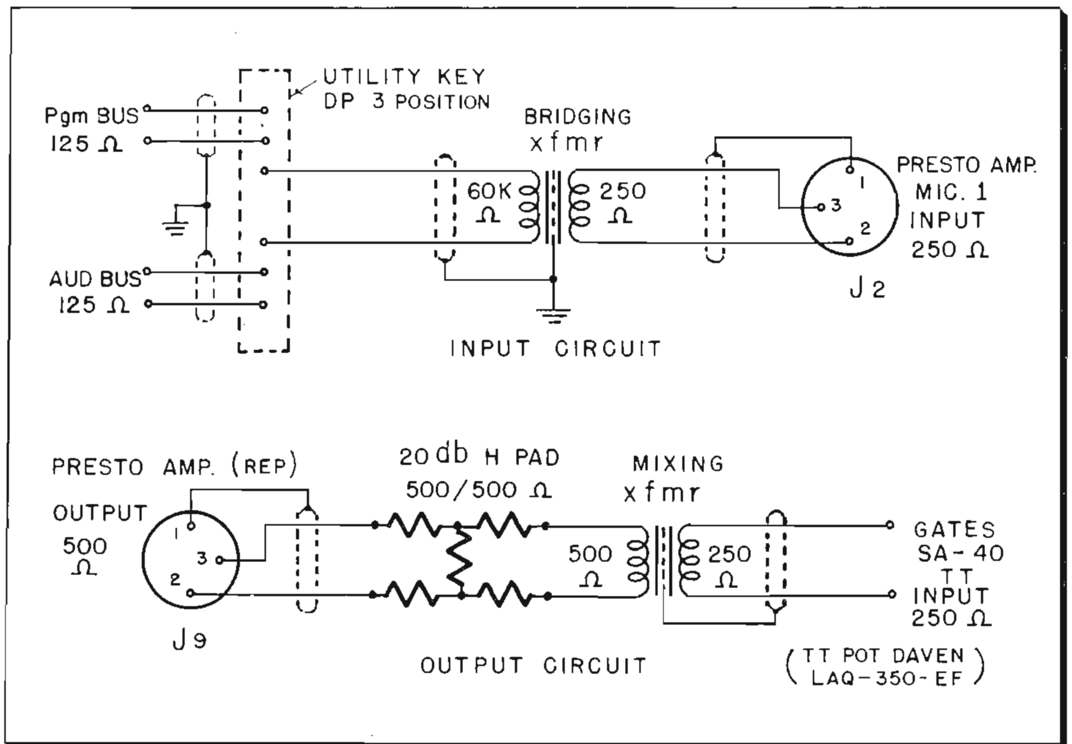
WE operate a Presto PT-900 tape recorder and amplifier in conjunction with our Gates SA-40 console and found the following circuit permitted extremely flexible operation.

An unused TT input channel of 250 ohms (pot has "cue" position) and an unused utility key on the console provided the necessary input/output switching circuit. Usual circuit break-in connections are available at terminal strips.

The utility key is basically a double-pole-three-position type, therefore shielded leads from the 125 ohm program and audition busses were wired from the proper break-in connections to the key. The key arm feeds the 60,000 ohm primary of a standard bridging transformer, while the 250 ohm secondary feeds the Presto amplifier mike #1 jack. Mike #1 potentiometer and master gain potentiometer are adjusted to obtain proper input level while tape recording programs. The output of the Presto amplifier is fed into a 20 db pad, 500/500 ohms and a standard mixing transformer to complete the circuit. Tape cuing is simplified by the insertion of TT potentiometer on the console through regular cuing system.

We can tape a program being broadcast or from main studio, remote lines etc., while broadcasting regular programs. An unusual echo effect, long or short, can be obtained if a program is taped from the program bus, and at the same time the playback potentiometer on the Presto amplifier is opened slightly. Some experimenting and practice will be necessary to obtain a good echo.

Flexible circuit provides facilities for reproducing, recording, and reverberation



$$$ FOR YOUR IDEAS

Readers are invited to contribute their own suggestions which should be short and include photographs or rough sketches. Typewritten, double-spaced text is requested. Our usual rates will be paid for material used.

Reducing Tape Recorder "Down Time"

DON V. R. DRENNER, KGGF, Coffeyville, Kans.

USERS of the AMPEX series 400 tape recorders may find the following hints helpful in reducing "down-time." The adjustment of the "Take-up Torque" switch—a Microswitch actuated by an end-of-thrust collar on the Capstan Solenoid—is critical. If this switch does not open when the capstan is engaged, full power is transmitted to the take-up reel. A slightly high-pitched sound for speech, or loss of lows in music, will indicate that the switch is not opening. The "snap" sound, evident when the switch is opening and closing, can be misleading when the adjustment is made, because there is considerable tension not only on the Microswitch arm but on the Solenoid sleeve. Adjust carefully, and then measure the voltage at the motor to be sure the current limiting resistor *is* being placed into the circuit when the switch opens.

If your machine uses Eastern Air Devices motors there will probably be no oil cups. However, despite the lack of oil cups these motors require lubrication. Carefully examine to find the two oil holes, and probe with a paper clip (straightened out to form a 1 in. length) to be sure the hole in the outer casting aligns with the hole feeding the felt wick of the bearing housing. If the hole does not align, remove the motor and rotate the bearing to a proper fit. The bearings are held in with a retaining spring that is easily removed. Then oil with 10 drops of SAE 20 every six months—or oftener, depending on the amount of use. Lubrication of these motors is important, as they do not have end thrust bearings. (If run dry the fiber washer, and eventually the shaft and bearing, will fail.) The Bodine motors which AMPEX also fits have oil cups, and lubrication of these, while equally important, is self-evident.

The AMPEX manual cautions against contamination of the brake drums by touching with your fingers. A deposit of oil film is transferred and the brakes will be inoperative. The drums and felt surfaces of the brakes can be cleaned with small amount of carbon tet. Then sand lightly with Wet-Or-Dry abrasive both the drum and felt surface of the brake. This roughens the felt slightly and removes a slight deposit of film which seems to adhere from the drive pulley of the turn table motor.

A word of caution: Always wipe excess oil away, preferably with a solvent. Contamination of driving pucks, drums, etc. with oil is the cause of most troubles on current machines.

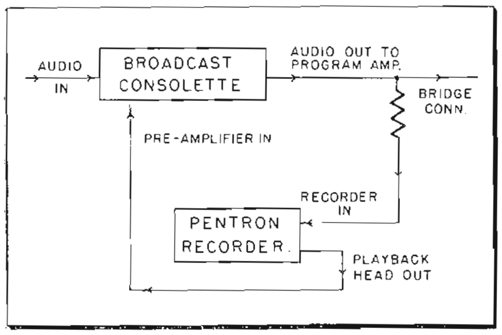
Amplifier for Echo and Special Effects

EUGENE O. EDWARDS, Chief Engineer, KBIX, Muskogee, Okla.

FOR some time we felt a need for echo and special reverberation effects as a production aid to our disc jockey shows and recording spot announcements. We tried several methods and found that tape recorders with separate playback and record heads were most suited to our needs. However, the price of these recorders is high.

We had a small Pentron 9T3 tape recorder which we used for special events and as a salesman's audition playback. It has two speeds: 7½ and 3¾ in ,1 set. A new mounting bracket was made for the heads to accommodate the third head and the original erase and record/playback heads were moved slightly to mount the extra head. The tape guide shaft was moved slightly and a new spring added to decrease the pressure of the felt fingers on the pole pieces of the two record/playback heads. The tape was aligned and the pull and drag on the tape properly adjusted.

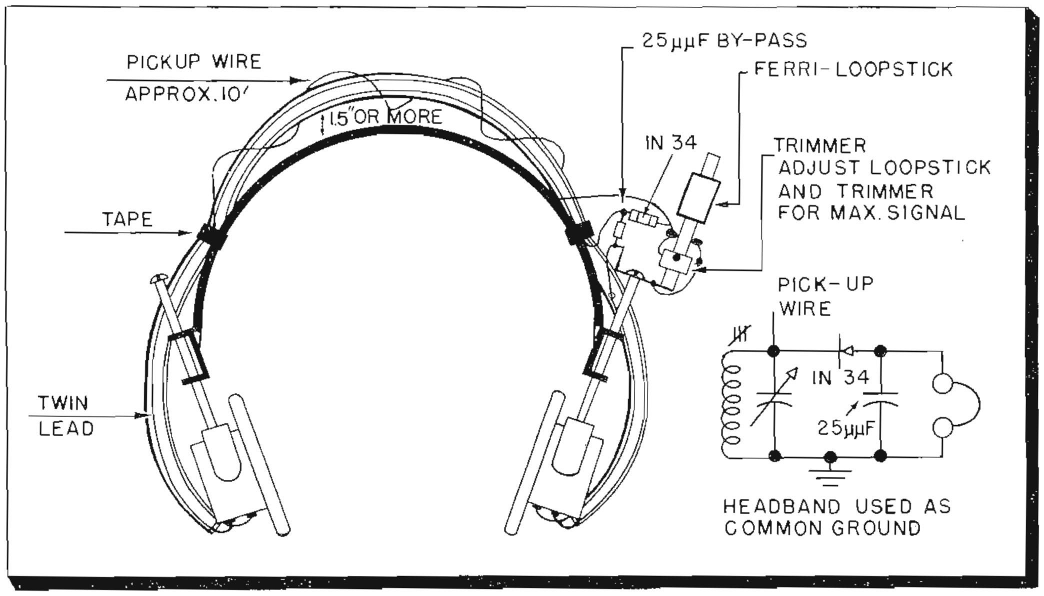
The output of the new head, (which is high impedance) was tied to a standard phone jack on the front panel of the recorder. This



Third head on Pentron recorder provides cheap echo and reverberation effects

completed the actual work on the recorder. Details of mounting the head are not given because there are other recorders on the market that will permit this conversion and placement of the heads can be decided in individual cases.

To obtain our special effects from this recorder, the input is bridged across the output of the broadcast console, and the output of the new playback head is matched to a preamplifier input to the console. The tape recorder is placed on the "record" position and the motor started. This allows the output of the recorder to be fed back into the input of the console with 0.133 sec. delay at 7½ in./sec. and 0.266 sec. delay at 3¾ in./sec. The amount of signal fed back from the record head can be controlled by the preamplifier gain.



Novel personal station monitor built around "Ferri-Loopstick" uses crystal detector

Personal Station Monitor

ROBERT LALUZERNE, WJPG, Green Bay, Wisc.

A MONITOR, built around the "Ferri-Loopstick" coil, is useful when it becomes necessary to leave the transmitter building. The coil combines the high Q and small size which are essential for the job.

High impedance commercial type phones were used so they could be connected across the tuned circuit without materially reducing the Q. The regular leads were removed from the phones and a piece of 300 ohm twinlead used to connect them. Twinlead was used because it provided a convenient method of connecting the phones and also could be used as a support for the pickup wire. The "Loopstick," trimmer capacitor, by-pass capacitor and the 1N34 crystal were mounted on the end of one of the earphone brackets. The method of mounting is shown in the diagram.

This simple monitor provides enough volume to be heard at least 100 feet from the transmitter and is useful when making "doghouse readings," etc.

Tape Duplicator

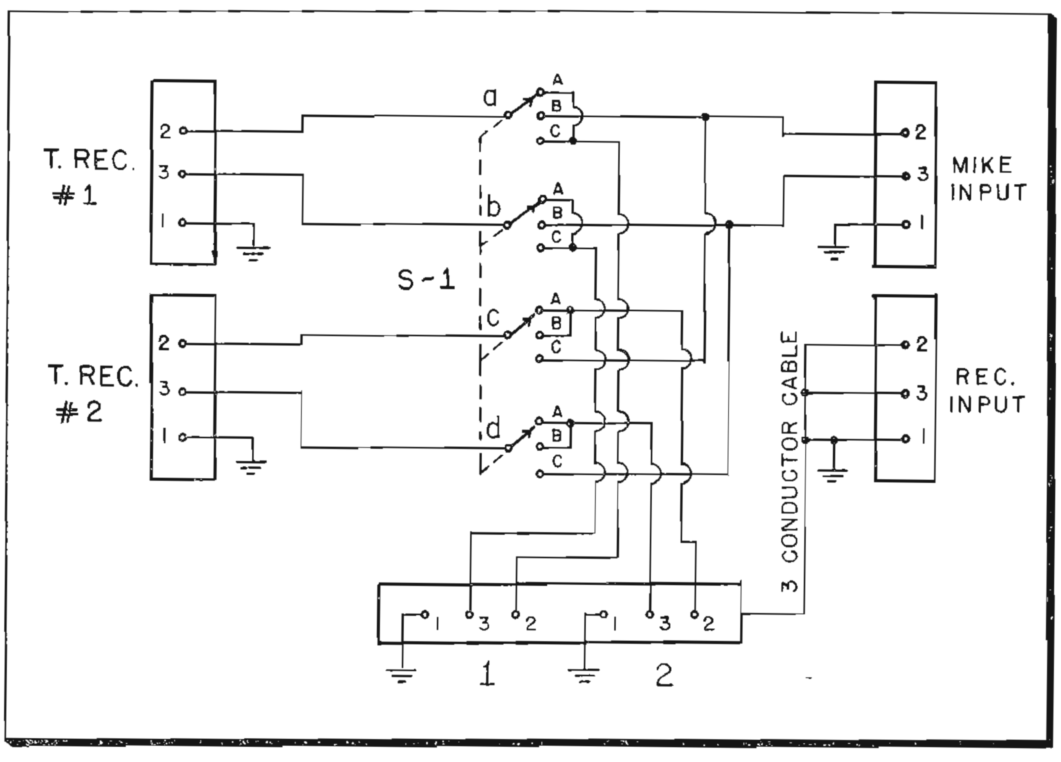
JAMES T. GRACE, Chief Engineer, WFCB, Dunkirk, N. Y.

OUR engineers found it necessary to duplicate some recording tapes and an inexpensive switching arrangement was constructed to accomplish this. Two Magnecord PT6-AH tape recorders, a PT6-J amplifier, and a Magnecord switcher PT6-HT are used. The tape duplicator was designed so that no internal wiring was changed.

The duplicator was built on a 3x5 in. chassis with an additional plate added so that only the chassis ends are open. A 4-pole 3-position rotary switch is mounted on this cover plate. Two Cannon XL-3-13 female

(*Continued on page* 112)

Tape duplicator control chassis eliminates equipment wiring changes when dubbing



Evaluation of High-Performance

By SIEGFRIED R. HOH
Components and Systems Lab.
Weapons Components Div.
Wright Air Development Center
Dayton, Ohio

PART TWO OF TWO PARTS

THE loss tangent or its equivalent factors have been depicted in Fig. 6 for different materials. Several of these curves, particularly those for powdered materials, were computed from loss coefficients.[12,13] In these cases, a flux density of 10 gauss was assumed. Some publications state that the flux densities were very low and the hysteresis losses negligible. It can be assumed that the flux densities involved in Figs. 6, 7, and 8 are 10 gauss or less, except the permeability of Supermalloy which is given for $B_m = 20$ gauss. At these low flux densities, the hysteresis losses are actually only a small part of the total losses and small differences in flux density do not affect loss data substantially.

Eddy current losses play a more important role. Such losses prevail in metallic materials at higher frequencies because the losses are proportional to the second power of frequency. Eddy current losses are also proportional to the second power of material thickness. This illustrates the importance of subdividing a metallic material into thin laminations or powdered particles. The reduction of losses by the subdivision of the material can be noted in all characteristics. For example, see data on 4-79-Mo Permalloy (Fig. 6) with the lamination thickness being 0.5, 1, and 14 mil.

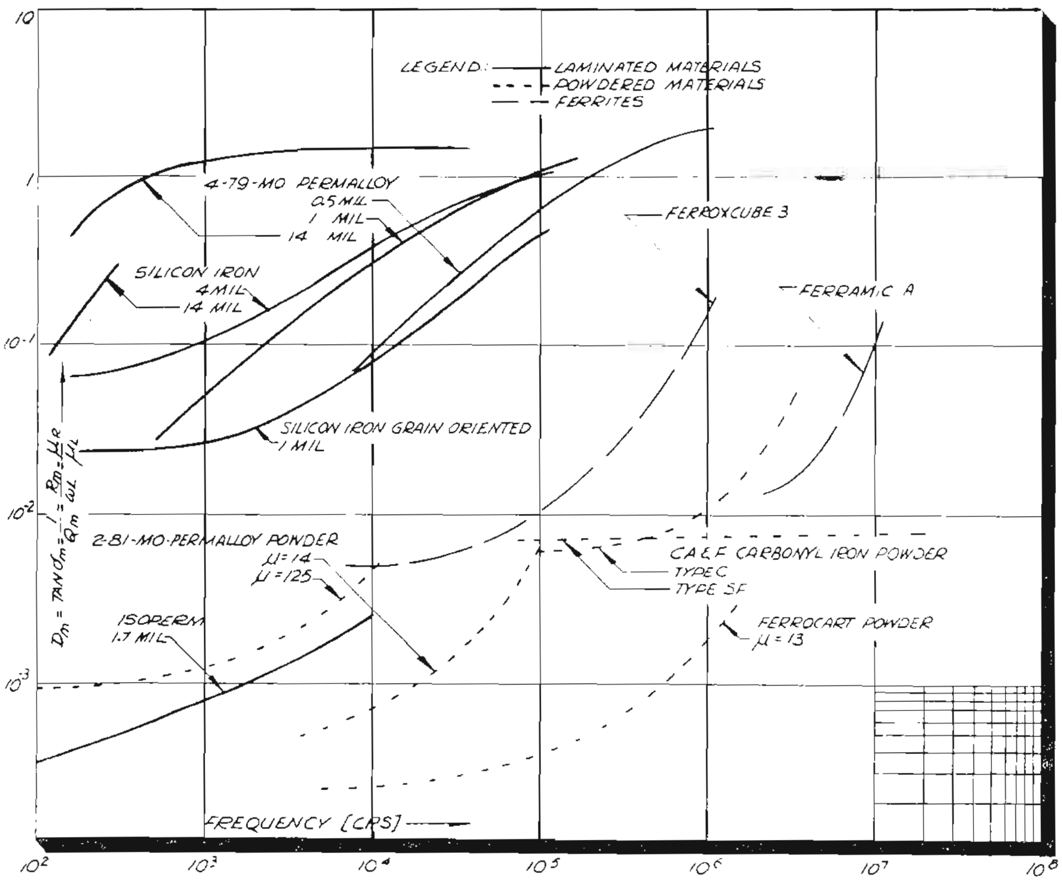
Loss Reduction

A further reduction of total losses by finer subdivisions of metallic materials is limited. Coercive forces, in particular, will increase as the material thickness is further decreased. Extremely thin laminations cannot be stamped and stacked but have to be wound into toroidal cores. The thickest laminations presently produced are about 0.15 mil. Further substantial reductions cannot be expected because of the difficulties in rolling the materials and because of the decrease in magnetic qualities such as an increase in coercive force. High-frequency applications of thin laminated materials are pulse transformers. magnetic pulse generators, digital computers, and others.

There appears to be a distinct difference in losses (see Fig. 6) by a factor of more than 10 between the laminated materials and the good powdered and ferrite materials. An exception is Isoperm, a German loading coil material which is unique in the field of laminated materials insofar as the dissipation factor is concerned. In Isoperm, losses have been reduced down to those of the best powdered materials. The permeability of Isoperm is, however, substantially lower than that of other laminated materials. High permeability materials such as laminated Mo-Permalloy have the highest losses, while silicon-iron is better as far as losses are concerned. (Compare 1 mil. 4-79-Mo-Permalloy with 1 mil. silicon-iron, Fig. 6.)

From Fig. 6, it is easy to see that good powdered and ferrite cores have much smaller losses than laminated materials. Powdered core materials, sometimes designated as "Polyirons," have long been known. They consist of powdered pure iron, alloys, and organic binders, or powdered ferromagnetic oxides.

Fig. 6: Core loss of laminated, powdered and ferrite materials at low flux densities



Powdered Iron Cores

Problems of powdered iron core development are: (a), to produce uniformly fine powders; (b), to insulate the metal particles from each other; and (c), to make the proportion of metal high in relation to the binder in order to obtain a relatively high permeability. These problems illustrate that compromises have to be made and that there are optimum compositions for individual frequency ranges. Low losses at rising frequency can only be maintained by decreasing the permeability. Because of the many series gaps in powdered material, permeabilites are inherently small and almost constant up to saturation. Permeabilities of commercial powdered core materials range loosely from 3 to 100. The effective permeability is still smaller in applications where the magnetic circuit is not closed.

It should be noted that loss data of commercial powdered cores are usually given as Q values of specific coils with specific cores. Such data

Magnetic Core Materials

Selection of proper material for desired application facilitated by the development of a "figure of merit." Suitability of ferrites for high frequencies shown

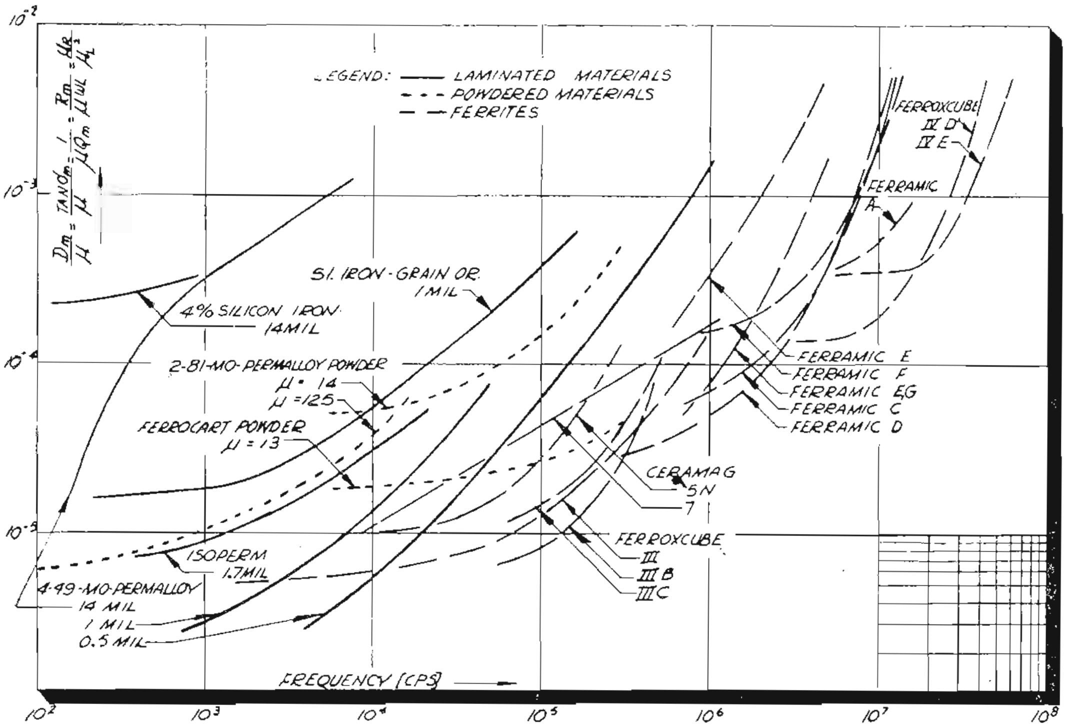


Fig. 7: AC characteristics of magnetic core materials at low flux densities

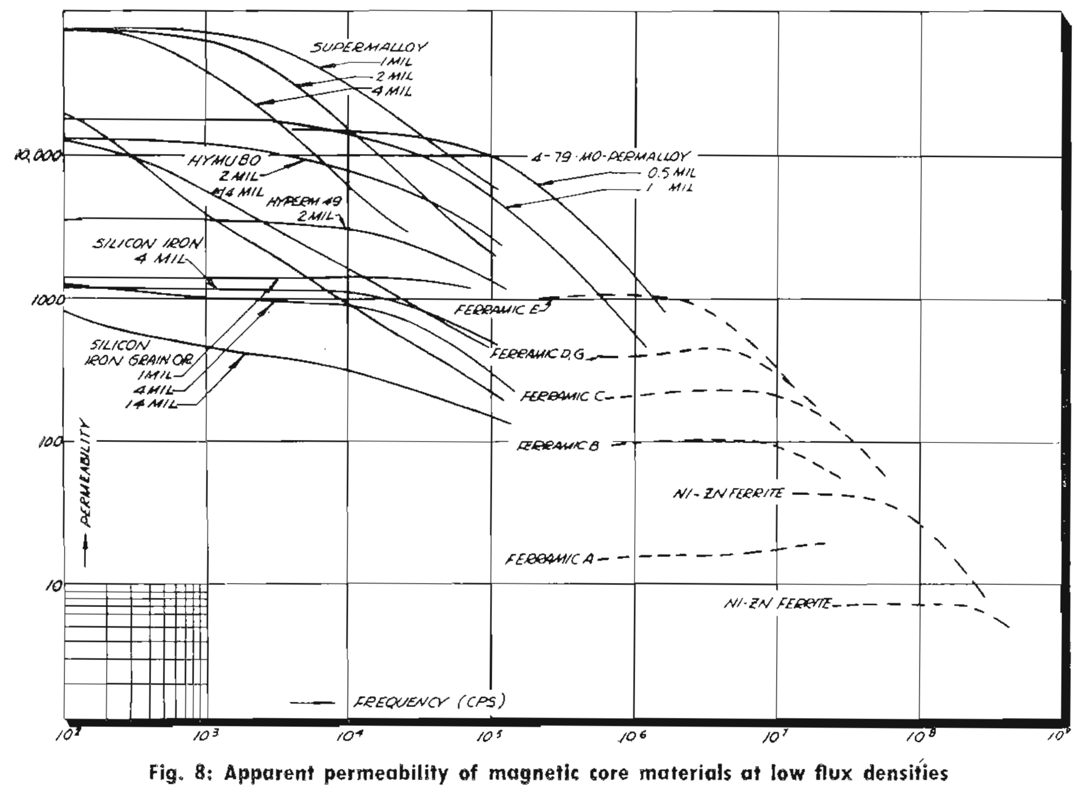


Fig. 8: Apparent permeability of magnetic core materials at low flux densities

are not suitable for material comparison on a universal basis.

Several powdered materials (shown by dotted lines in Fig. 6 and 7) have the lowest losses according to Fig. 6. This result is not very significant. The low losses of powdered cores are due mainly to their magnetic "dilution," that is, to the existence of a great number of small gaps between the ferro-magnetic particles. These gaps also account for the low permeability of powdered cores. Thus, the low losses of powdered cores are obtained at the expense of permeability. Actually, the best core material, with regard to losses, would be air or free space—in other words, no magnetic material at all. If size is of no concern, it is known that low inductor losses can be obtained without cores. This illustrates the limited significance of loss data alone and the necessity for including the permeability in a comparison.

The introduction of an air gap in laminated or ferrite cores will also reduce losses and make these materials competitive. Q factors of approximately 600 have been reported on inductors which utilize ferrite pot cores with air gaps.[18] According to Snoek,[3] the loss reduction of ferrite cores, because of an air gap, is proportional to the reduction of permeability. This relationship can be expressed by the simple ratio:

$$D_m/\mu = D_m'/\mu \qquad (3)$$

where D_m and μ refer to a closed ring core, while D_m' and μ' refer to the same properties of a core with air gap. In addition to reducing losses, an air gap also reduces the effect of temperature on permeability.

The term D_m/μ appears suitable for use as a general rating because: (a), it combines the most important core characteristics as D and μ; (b), it extends the applicability of the rating to ferrite cores with air gap; and (c), it can be computed easily from individual loss coefficients as defined by Legg.[12]

Rating Materials

Fig. 7 depicts D_m/μ values versus frequency. Although the number of materials had to be limited, the following conclusions and ratings appear justified: powdered cores, which were superior in Fig. 6, are surpassed by laminated and ferrite cores; laminated cores rate better up to more than 10,000 CPS from which frequency ferrites appear to be better. The unique position of Isoperm in Fig. 6 has been lost, and, in Fig. 7, Isoperm rates with other laminated materials. Ferrites which are often considered to fill a gap between laminated and powdered materials are found to be superior over powdered materials. Therefore, it may be expected that ferrites will come into wider use for high frequency applications. At present, the bulk of ferrite applications are in TV receivers.

There are various other factors which cannot be incorporated in a universal rating but which may determine the selection of a material. Laminated cores, for example, are strain sensitive and often available as closed toroids only. Ferrites and powdered cores are relatively insensitive, substantially less in weight than laminated materials, and can be formed into a large variety of core shapes. The maximum operating temperatures of ferrite and powdered cores are, as a rule, lower than the maximum operating temperatures of laminated materials.

CORE MATERIALS (Continued)

A less comprehensive but rather interesting diagram is obtained if the permeabilities of materials are plotted versus frequency, as in Fig. 8. Permeabilities are given for the low flux densities (as discussed in relation to Fig. 6) and can be termed initial permeabilities unless a more rigid definition (see Table III) excludes several of the data in Fig. 8.

The apparent permeability (see Table III) of a toroidal metallic core decreases with frequency because the eddy current shielding results in a lower flux density in the inner portions of a ferromagnetic lamination. This well-founded explanation is also substantiated in figure 8 where the permeabilities of thicker laminations decline faster at rising frequency. As in Fig. 6 and 7, Fig. 8 shows that the materials with better dc or low-frequency characteristics are surpassed at higher frequencies. Note that 2-mil Hymu 80 surpasses the initial permeability of 2-mil Supermalloy at approximately 40,000 CPS, although the resistivity of Supermalloy is slightly higher.

Laminated Cores

Lamination thickness and resistivity are the principal factors governing the reduction of the "apparent" permeability of laminated metallic cores over frequency. The "true or intrinsic" permeability of laminated metallic cores can be derived from the apparent permeabilities by calculating and eliminating the eddy current effect in the materials. This means that the true or intrinsic permeability could be realized and measured if the eddy current shielding effect could be avoided as is the case in some ferrites. The true or intrinsic permeability is of great interest for the study of both the ferromagnetic substances at microwave frequencies[2] and the phenomena which reduce the relative permeability to unity. The true permeabilities of metals are rather constant up to approximately 10^8 CPS and reduce to unity in the region from 10^{10} to 10^{11} CPS.

From the standpoint of core-material utilization, the apparent permeability, as plotted in Fig. 8, is of main concern because it represents the permeability which can be utilized in a core. Extrapolation of Fig. 8 indicates that the apparent permeabilities become unity in the region slightly above 10^9 CPS.

Another interesting result of Fig. 8 is the fact that the highest apparent permeabilities of all available materials, as plotted over frequency, can be represented by a rather smooth envelope even though both laminated materials and ferrites are represented. The transition between both types of materials occurs at approximately 2 MC and is actually smoother than shown, taking into consideration that materials which are thinner than 0.5 mil are available. The practical significance of the envelope in Fig. 8 can be interpreted as a line which limits the highest initial permeabilities that can be obtained with the best magnetic cores at any given frequency.

Thus far in this report, the term "permeability" is understood to determine the impedance Z_m of a toroidal core which under simplifying assumptions reads:

$$Z_m = R_m + j\omega L = R_m + j\omega\mu N^2 A/l \quad (4)$$

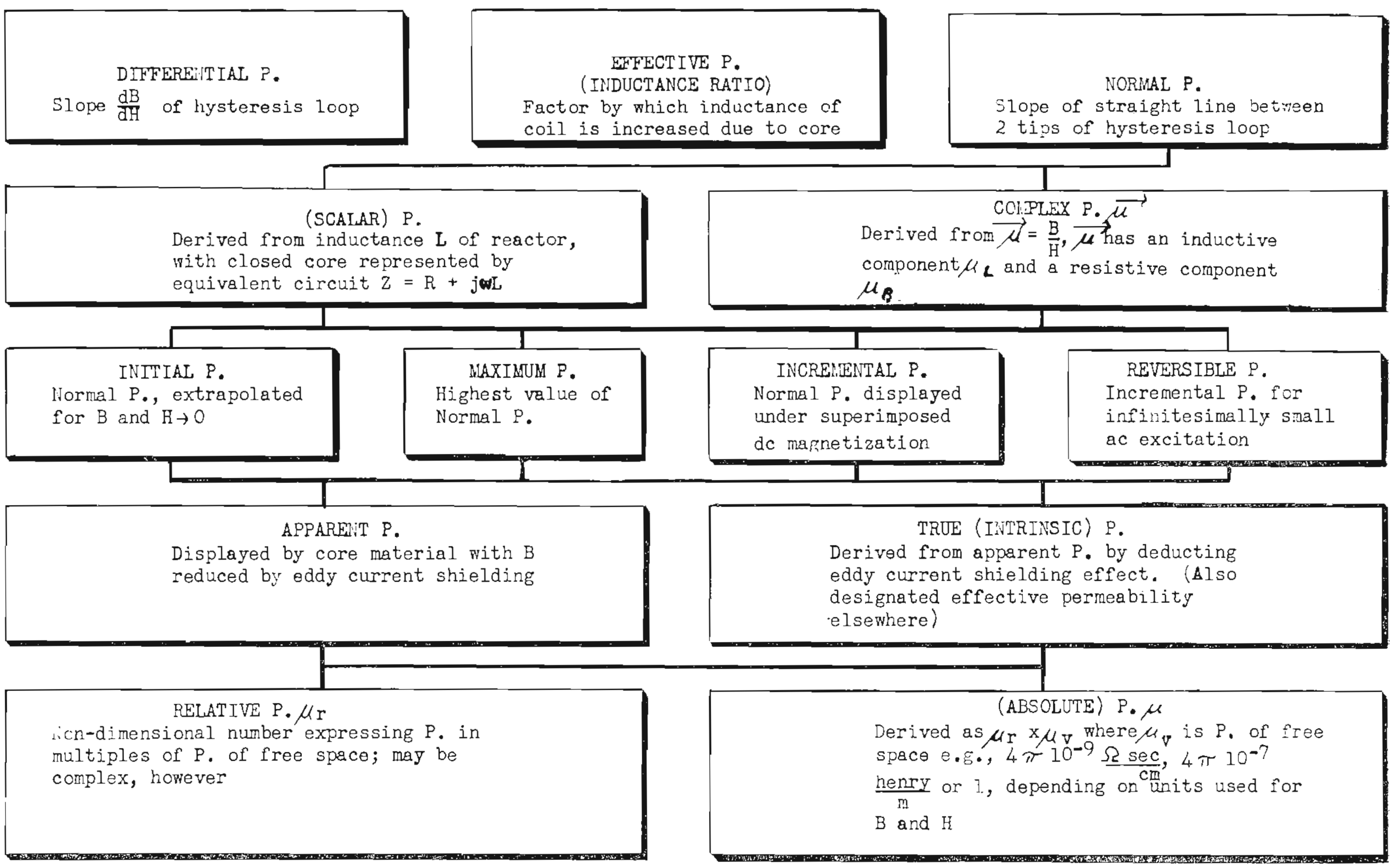
If, however, the permeability is to be derived according to the definition

$$\mu = B/H \quad (5)$$

a discrepancy appears. While B is in quadrature with the applied voltage according to $E_L = N d(AB)/dt$, the magnetizing force is not in quadrature because H, according to definition, is proportional to the current which has a loss or in-phase component. Eq. (5) can be applied to ac magnetization only if a phase angle

(*Continued on page* 157)

TABLE III: PERMEABILITY DEFINITIONS PERTINENT TO CYCLIC OR ALTERNATING MAGNETIZATION



Directional Coupling with Transmission Lines

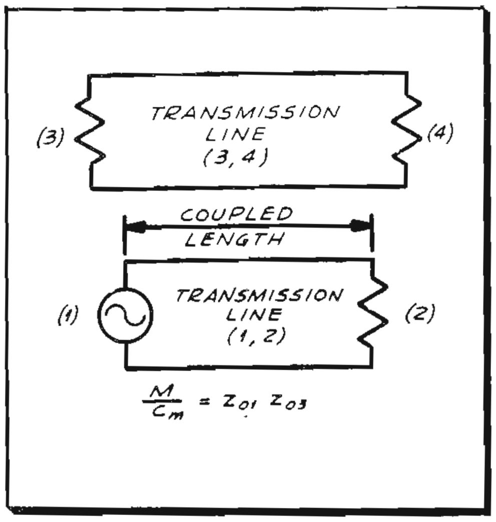


Fig. 1a: Coupled transmission lines circuit

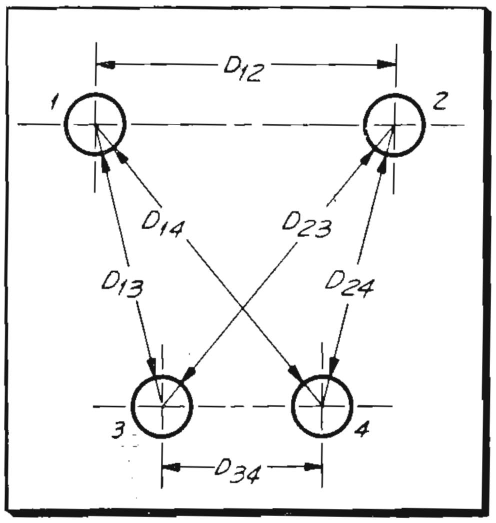


Fig. 1b: Cross-sectional view of two lines

Application of couplers, widely used in wave-guide circuitry, holds promise for lower radio frequencies. How to utilize open-wire lines

By WILLIAM L. FIRESTONE, Head, Special Design Section, Microwave Research Dept., Motorola, Inc., 4545 Augusta Blvd., Chicago 51, Ill.

DIRECTIONAL couplers have found wide use for many years in waveguide applications for such purposes as measuring reflections, monitoring power, multiplexing and mixing. All of these applications make use of the characteristic that power flowing in one direction in the main transmission line induces a power flow in only one direction in the secondary transmission line.

Many different kinds of wave-guide directional couplers are in present day use. However, it is the general purpose of this paper to analyze the directional coupling effects of open wire transmission lines which are used at the lower radio frequencies.

Other devices called "Wave Selectors" and "Reflectometers" are devices which are intimately related to the "Directional Coupler" and hence deserve some comment.

The following terms are now in common usage:

Wave Selector:

A device whose output is substantially proportional to one or the other of the two traveling waves on the line. The wave selector causes little or no reflection on the line to which it is coupled.

Directional Coupler:

A device which couples together lines so that traveling waves are induced in one of the lines proportional to the traveling waves in the other line. The directional coupler causes little or no reflection on either of the two lines it couples together.

Reflectometer:

A set of two wave selectors used to measure the forward and backward traveling waves, respectively, for the purpose of determining the reflection coefficient of terminal devices.

From the above we see that wave selectors, directional couplers and reflectometers may all assume the

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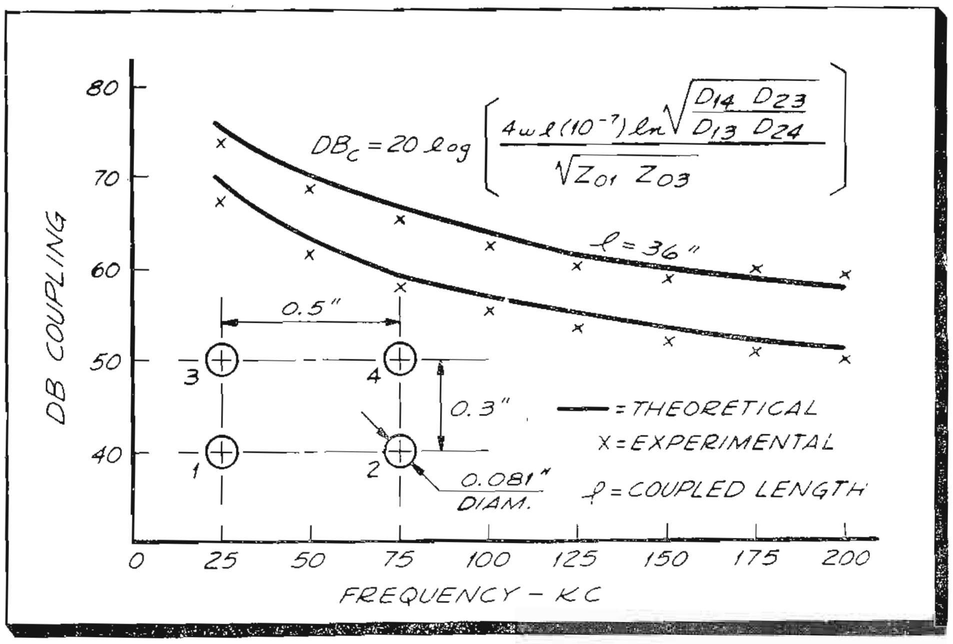
Fig. 2: (1) Mutual inductance and mutual capacitance between lines. Fig. 3: (r) Coupling-frequency characteristic of four-wire system

$$C_m = \frac{4\epsilon_r (10^{-7})}{Z_{01} Z_{03}} \ln \sqrt{\frac{D_{23} D_{14}}{D_{13} D_{24}}} \qquad \frac{\text{FARADS}}{\text{METER}}$$

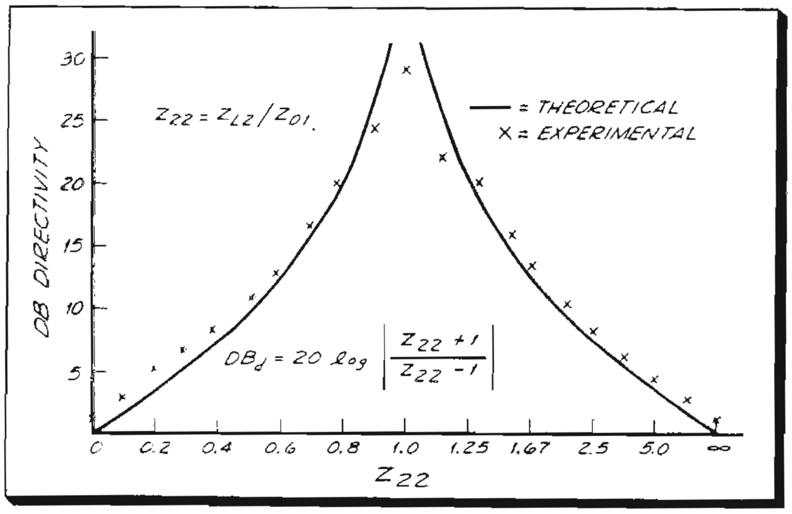
WHERE FOR AIR $\epsilon_r = 1.0$

$$M = 4(10^{-7}) \ln \sqrt{\frac{D_{23} D_{14}}{D_{13} D_{24}}} \qquad \frac{\text{HENRIES}}{\text{METER}}$$

$$\frac{M}{C_m} = \frac{4(10^{-7}) \ln \sqrt{\dfrac{D_{23} D_{14}}{D_{13} D_{24}}}}{\dfrac{4(10^{-7})}{Z_{01} Z_{03}} \ln \sqrt{\dfrac{D_{23} D_{14}}{D_{13} D_{24}}}} = Z_{01} Z_{03}$$



DIRECTIONAL COUPLING (Continued)



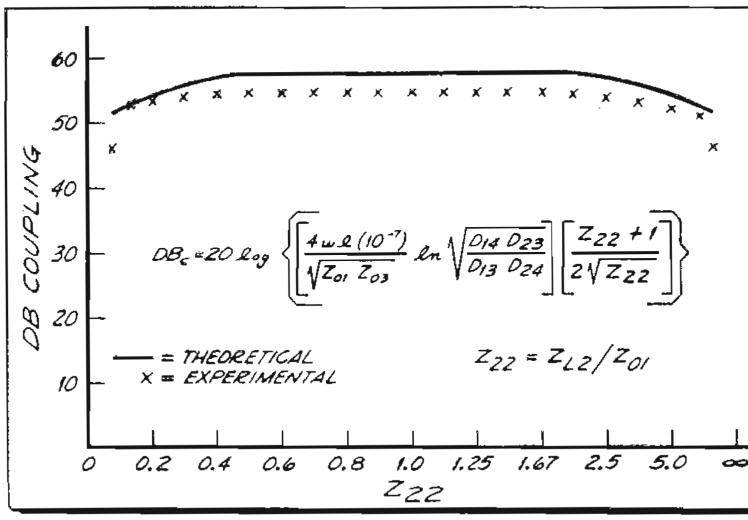


Fig. 4: (l) Directivity characteristic with normalized impedance varied. Fig. 5: (r) Directivity characteristic with mismatch taken into account

same approximate physical form, in which case the only difference between them would be the specific application for which each is used. However, only the directional coupler specifically requires the coupling of two transmission lines. The following analysis is based entirely upon directional coupler concepts.

A review of the literature, which included the analysis of papers that were primarily concerned with microwave directional couplers as well as those papers which were concerned with coupled open-wire transmission lines, indicated that in no instance has a complete theory been developed for the directional coupling characteristics between open-wire transmission lines.

$$DB_d = 20 \log \left[\sqrt{\frac{Z_{33}}{Z_{44}}} \left| \frac{Z_{22} Z_{44} + 1}{Z_{22} Z_{33} - 1} \right| \right]$$

a) $Z_{11} = Z_{22} = Z_{33} = Z_{44} = 1$
b) $Z_{33} Z_{22} = 1,\ Z_{11} Z_{44} = 1$
c) $Z_{33} Z_{22} = 1,\ Z_{11} = Z_{44} = 1$
d) $Z_{33} = Z_{22} = 1,\ Z_{11} Z_{44} = 1$
e) $Z_{33} Z_{22} = 1,\ Z_{11}$ OR $Z_{44} = 1$
f) $Z_{11} Z_{33} = 1,\ Z_{22}$ OR $Z_{33} = 1$
g) $Z_{33} Z_{44} = 1,\ Z_{22} \neq 1$ AND $Z_{11} Z_{44} \neq 1$
h) $Z_{44} Z_{11} = 1,\ Z_{22} \neq 1,\ Z_{33} \neq 1$ AND $Z_{22} Z_{33} \neq 1$

Fig. 6: Impedance relations for directivity

The investigation which led to this paper was therefore initiated with the following primary purposes:

1. To determine if a directional coupler utilizing two open-wire transmission lines was possible and any limitations that might exist regarding the physical configuration.
2. To derive analytical expressions for the directivity and coupling, with or without reflections being present on either or both transmission lines.
3. To derive an analytical expression for the coupling with any length of coupled section when both transmission lines are matched.
4. To consider the directivity and coupling characteristics for transmission systems other than open two-wire transmission lines.
5. To experimentally verify the above.

Whenever two transmission lines are coupled resultant waves will be induced on the secondary transmission line. These waves may be considered to be the result of capacitive and inductive coupling. Using this concept a "characteristic" equation (valid for short coupling lengths) which must be satisfied before directional coupling can occur, was determined. Fig. 1 shows the configuration under consideration as well as the derived characteristic equation. This equation can be seen to involve the mutual capacitance and the mutual inductance between two coupled transmission lines which are matched. The impedances shown are the characteristic impedances of the transmission line [1,2,3,4].

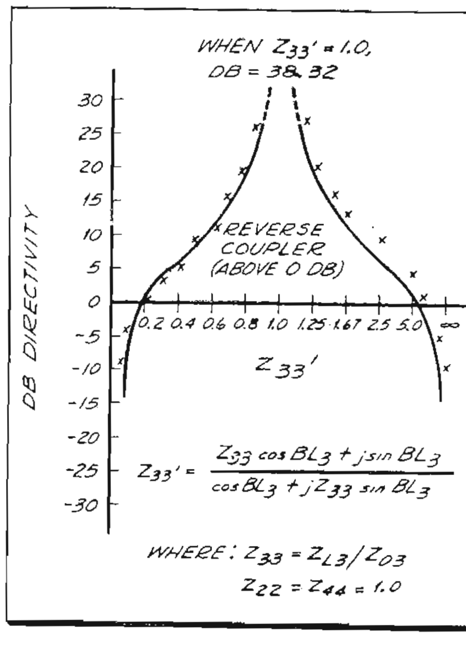
Four Wire System

To prove that the four wire system of Fig. 1 is in fact a directional system it is necessary to solve for the mutual capacitance and mutual inductance existing between the two coupled open-wire transmission lines and see if they satisfy the characterisitc equation. Solving for these quantities we will obtain their values as shown in Fig.. 2. [16] Taking their ratio, as indicated in lower part of Fig. 2, shows that the values of M and C_m identically satisfy the required equation. Hence, two coupled open-wire transmission lines possess directional coupling characteristics.

The reason why a wave traveling on the main transmission line results in a single wave traveling on the secondary transmission line may be understood when one considers the effects of the mutual capacitance as well as the mutual inductance separately. Each of these mutuals set up a pair of oppositely traveling waves on the secondary line. However, the phase differences existing between these waves, is such as to cause a complete cancellation of waves in the forward direction and a complete addition in the reverse direction. Two coupled transmission lines, therefore, represent a reverse coupler. The ratio of the power in the secondary line which is going in the desired coupled direction to that which is traveling in the undesired direction is called the directivity ratio. For matched transmission lines this ratio is infinite.

With the aid of the mutual capacitance and mutual inductance between two coupled transmission lines which are matched, an analytical expression for the coupling ratio can be obtained. This coupling

Fig. 7: Directivity with Z'_{33} mismatched



ratio is defined as the ratio of the power received in the desired direction on the secondary line to the power incident at the input terminals of the primary, or main, line. The resultant coupling equation is this power ratio expressed in decibels. Several different experimental curves of frequency versus coupling in decibels were obtained utilizing two different cross-sectional arrangements of the transmission lines. Fig. 3 shows two such curves with the derived expression or the coupling equation. The directivity was greater than 30 db. for all measured points.

By taking the derivative of the argument of the coupling equation with respect to a specified angle, α, and by setting this derivative equal to zero, one obtains a differential equation which, when solved for the angle, α, yields the optimum relative position between two coupled and matched transmission lines for a maximum power transfer to occur. The angle, α, is zero or 180° when the centers of all wires lie on the same straight line. Due to the complexity of solving the differential equation, graphical methods were used to obtain the desired information. Although almost any arrangement of parallel transmission lines will normally result in some transfer of energy, the arrangement yielding the highest degree of coupling for a symmetrical four-wire configuration is found to be that which requires the centers of all wires to lie on the same straight line.

Mismatched Systems

Since it is not always possible to completely match transmission lines, or in some cases a mismatch might even be desirable for other reasons, it would appear desirable to determine the effects of mismatched lines on the directivity and coupling of the system under consideration. One may approach this problem in a manner similar to that above, provided the mismatched terminations are taken into account. For this condition of primary line mismatch, one may derive analytical expressions for the directivity and coupling ratio.

Fig. 4 shows a plot of the theoretical directivity along with corroborating data and with the derived directivity equation shown in the lower center portion. Fig. 5 shows a plot of the experimental and theoretical coupling of the system taking into account the mismatch condition. Also, the equation for coupling is shown on Fig. 5. We may now observe that the part of the log term that is included in the first bracket is identical with that for the case of no reflections. This is readily checked by noting that, if $Z_{22} = 1$, the argument of the log term in the above expression reduces to the first bracketed term.

$$S = \left[\begin{array}{cc|cc} \bar{\gamma} & j\beta_3 & 0 & j\beta_2 \\ j\beta_3 & \bar{\gamma}^* & j\beta_2 & 0 \\ \hline 0 & j\beta_2 & \bar{\gamma} & -j\beta_3 \\ j\beta_2 & 0 & -j\beta_3 & \bar{\gamma}^* \end{array}\right] \qquad S = \left[\begin{array}{cc|cc} 0 & \alpha & 0 & j\beta \\ \alpha & 0 & j\beta & 0 \\ \hline 0 & j\beta & 0 & \alpha \\ j\beta & 0 & \alpha & 0 \end{array}\right]$$

Fig. 8a: (1) General scattering matrix. Fig. 8b: (r) Scattering matrix for matched condition

Wave Theory

This phenomena may be explained on a wave theory basis. An impedance mismatch on the primary line produces a reflected wave on that line. This wave on the primary line will also cause directional coupling to the secondary line. However, the primary and reflected wave on the main line travel in opposite directions and, hence, induce resultant waves traveling in opposite directions on the secondary line. Since some energy travels toward both terminations of the secondary line, the end result is a loss of directivity.

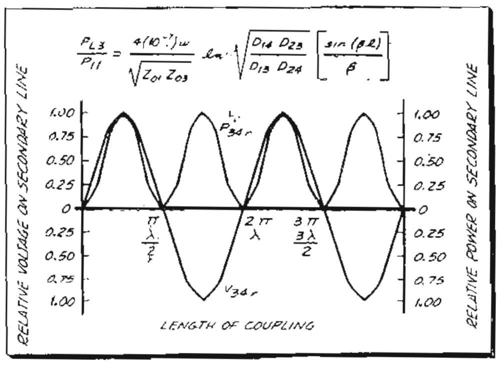


Fig. 9: Coupling effect on voltage and power

It is also possible to derive analytical expressions for the directivity ratio and coupling ratio, both expressed in decibels, for the case in which the primary line and the secondary line are not terminated in their characteristic impedances. In this instance, the effect of the primary transmission line mismatch is as stated in the preceding paragraph. The effect of mismatching the secondary transmission line, however, is equivalent to having each wave on the primary transmission line set up two resultant waves of different magnitudes on the secondary transmission line.

Two waves are set up on the secondary transmission line for each wave on the primary transmission line because the individual waves due to the mutual capacitance and mutual inductance have changed magnitude. This change in magnitude is due to the fact that the secondary line is mismatched. Hence, the waves due to the mutuals do not add to and cancel one another in the same manner as when the secondary transmission line is matched.

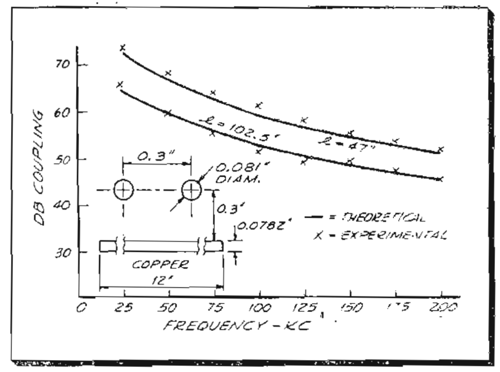
Fig. 6 shows the derived directivity equation. A little consideration of this equation will show that conditions (a), (b), (c), and (d), of Fig. 6 will yield complete directional coupling effects. That is, it is possible to put a signal in at any one of the terminals and a directional coupler will obtain. Furthermore, a partial directional coupler exists for any of the conditions from (e) to (h). Conditions (e) and (f) are three-terminal-pair directional couplers, whereas conditions (g) and (h) are two-terminal-pair directional couplers.

Loss of Directivity

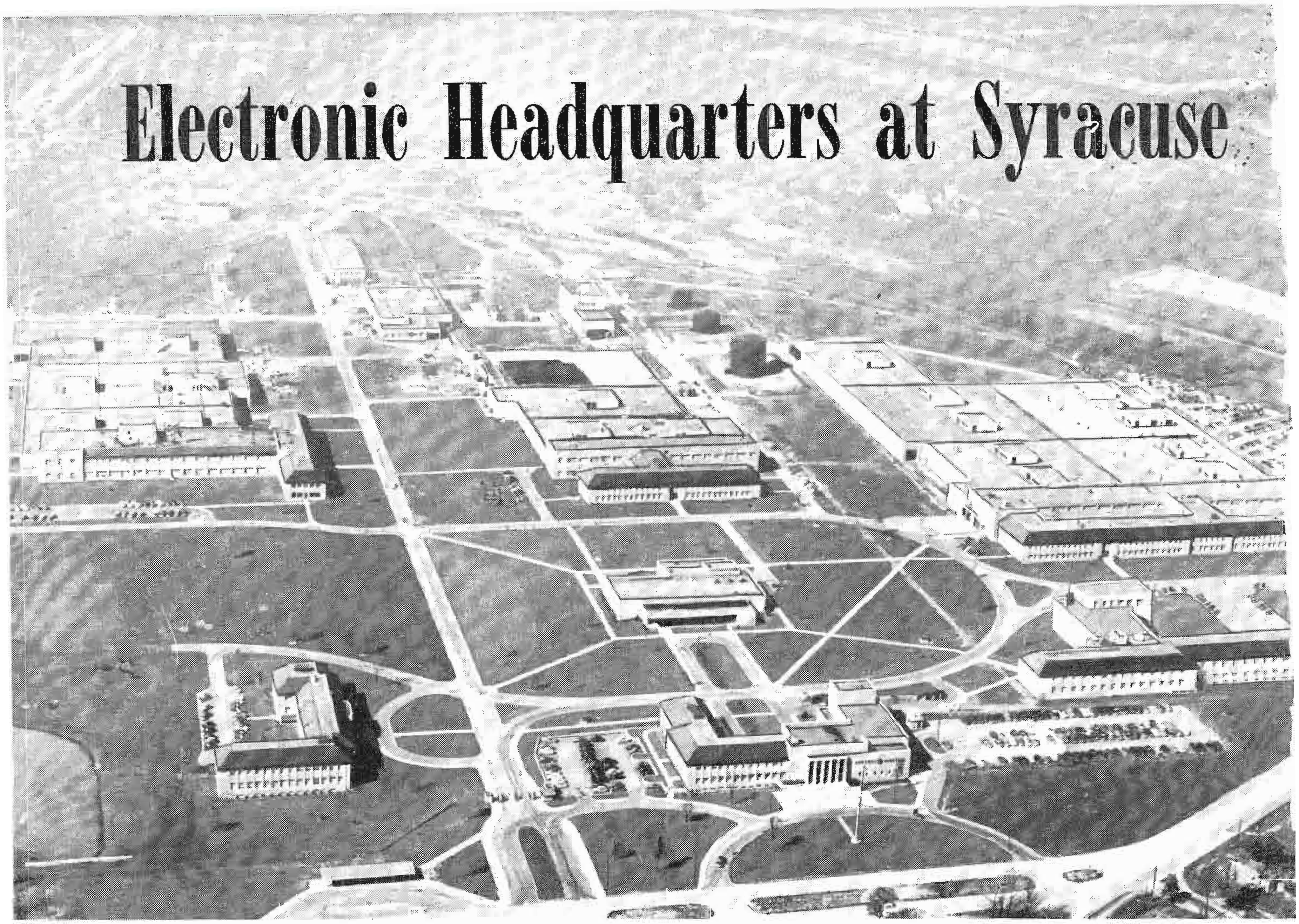
Generally speaking, a mismatch anywhere in the system results in a loss of directivity. However, as pointed out above, the directivity equation shows that if certain terminating impedances are in reciprocal relationship to each other, directional coupling with an infinite directivity ratio will occur even though each of the terminating impedances in question represents a mismatch. Physically this is equivalent to a mismatch at one pair of terminals setting up a reflection which is cancelled (insofar as directional coupling is concerned) by a mismatch at another pair. This is a surprising, as well as useful, result

(*Continued on page 172*)

Fig. 10: Two-wire coupling-frequency function



Electronic Headquarters at Syracuse



Air view of General Electric's Electronic Headquarters in Syracuse. For identification of buildings and activities see page 102

A review of past milestones as well as present and future engineering activities at one of the nation's foremost electronic equipment manufacturers

ON October 15 the General Electric Co. celebrated its "Diamond" anniversary. Seventy-five years ago, in 1878, the Edison Electric Light Co. was formed for the express purpose of developing a new source of light—the incandescent lamp. The event raised hardly a ripple in the newspapers of the day. But such was the humble beginnings of G.E.'s parent company.

In 1880, Elihu Thomson, a young professor, gave up teaching to cast his lot with the then infant electrical industry. In somewhat over half a century Thomson was granted some 700 patents. During this time he also built an organization of men who wrote brilliant and creative chapters in the history of electricity.

When the American Electric Co. was formed, the commercial development of the patents of Professors Thomson and Edwin J. Houston was one of the objects. Associated with them was E. Wilbur Rice, Jr., who later became president of General Electric. Out of this enterprise, in 1883, grew the Thomson-Houston Electric Co. at Lynn, Mass. Charles A. Coffin, a former shoe manufacturer, participated in this formation and subsequently in the active management of the company.

The early years saw rapid progress in the development of electricity. The great need was for cooperation

(*Continued on page* 102)

Interesting Facts about GE's Electronic Hqs.

1. Employs about 10,000 people, of which 1,100 are engineering personnel.
2. Took 100 engineers and draftsmen one year to design.
3. Covers 200 acres, with 35 acres under roof.
4. Resembles a college campus, vast lawns separating buildings, landscaped with wide variety of trees and shrubs.
5. Has 15 buildings, the largest housing operations of the Radio and TV, Cathode Ray Tube, and Commercial and Government Equipment Depts., and Electronics Laboratory.
6. Has extensive engineering product laboratories in addition to Electronics Laboratory.
7. A restaurant building which can accommodate 600 at one time, plus lunch bars in the manufacturing buildings.
8. An employees' store where G-E products can be purchased at discount.
9. Has auditorium which can seat 500.
10. Three and a half miles of railroad tracks.
11. Over five and a half miles of paved roads.
12. 17 parking lots with capacity for 4,500 cars.
13. All buildings have air conditioning and indirect heating, centrally controlled for temperature and humidity.
14. Over 32,000 fluorescent troffer type lighting fixtures are used in factory and office areas.
15. Has substation with 20,000 KVA capacity.
16. Power house with three boilers to supply heating and process steam.

Celebrates GE's 75th Anniversary

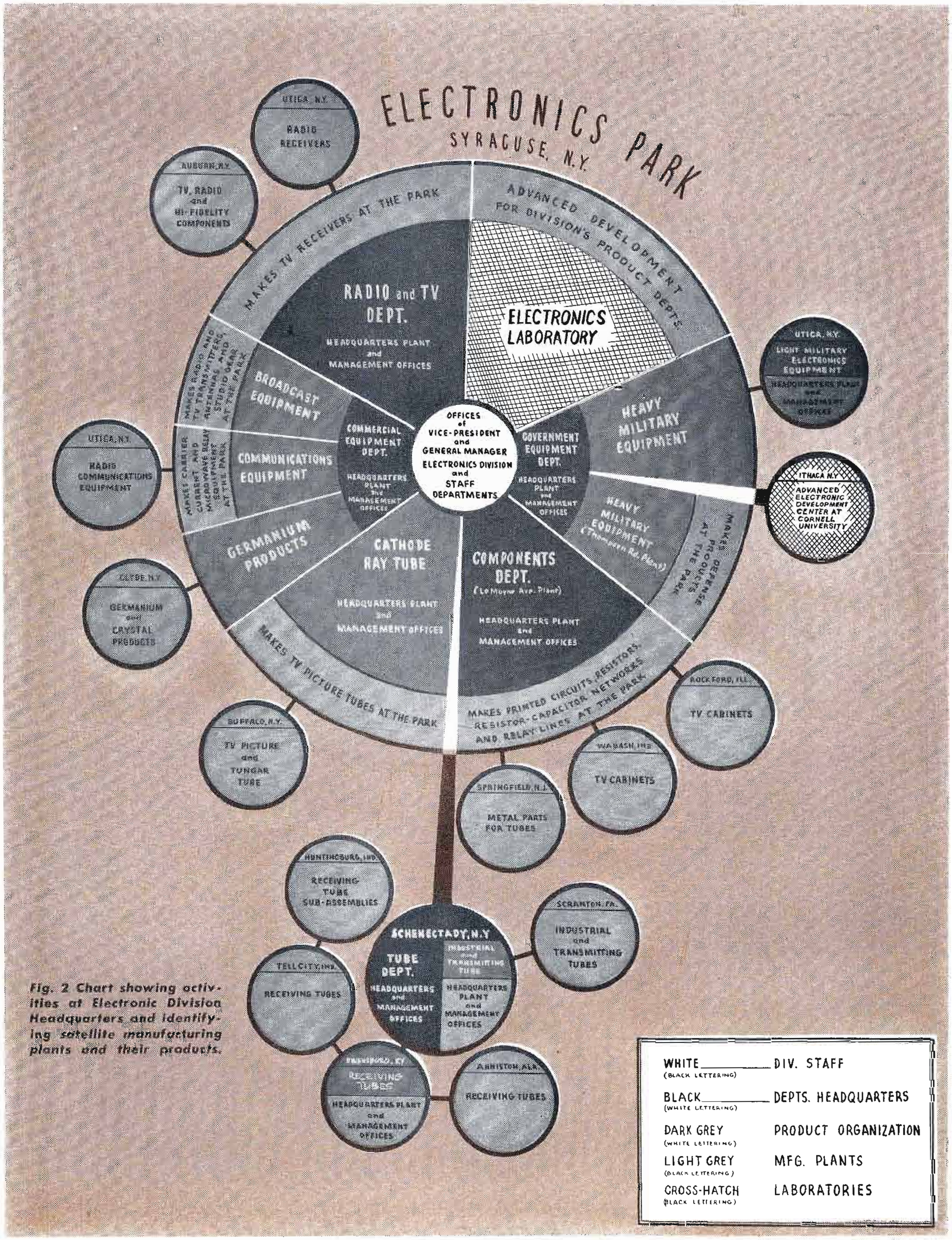


Fig. 2 Chart showing activities at Electronic Division Headquarters and identifying satellite manufacturing plants and their products.

How GE's Electronic Division Is Organized

PRESIDENT
RALPH J. CORDINER

EXECUTIVE VICE PRESIDENT
APPLIANCE AND ELECTRONICS GROUP
ROY W. JOHNSON

VICE PRESIDENT AND GENERAL MANAGER
ELECTRONICS DIVISION
WALTER R. G. BAKER

STAFF DEPARTMENTS

(POLICY AND ADVISORY FUNCTIONS PLUS CERTAIN GENERAL SERVICES)

- MARKETING — ERNEST H. VOGEL
- ENGINEERING — IRA J. KAAR
- MANUFACTURING — WILLIAM M. BARKER
- FINANCIAL — GEORGE L. CHAMBERLIN
- EMPLOYEE AND PLANT COMMUNITY RELATIONS — CLYDE H. HARRISON
- LEGAL AND PATENT — ROBERT M. ESTES

OPERATING DEPARTMENTS

(FULL RESPONSIBILITY ENGINEERING, MANUFACTURING, MARKETING, FINANCIAL, AND EMPLOYEE RELATIONS FUNCTIONS IN CONNECTION WITH PRODUCTS ASSIGNED.)

RADIO AND TELEVISION DEPARTMENT
GENERAL MANAGER
HERBERT RIEGELMAN
PRODUCTS: TV RECEIVERS, RADIO RECEIVERS, HIGH FIDELITY EQUIPMENT
PLANTS: SYRACUSE, N. Y.; AUBURN, N. Y.; UTICA, N. Y.

COMPONENTS DEPARTMENT
GENERAL MANAGER
EDWARD L. HULSE
PRODUCTS: TV CABINETS, TUBE PARTS, PRINTED CIRCUITS, FERRITE MAGNETIC PARTS, LOW POWER RESISTORS
PLANTS: SYRACUSE, N. Y.; ROCKFORD, ILL.; WABASH, IND.; SPRINGFIELD, N. J.

TUBE DEPARTMENT
GENERAL MANAGER
J. MILTON LANG

- RECEIVING TUBES
  GENERAL MANAGER
  L. BERKLEY DAVIS
  PRODUCTS: GLASS AND METAL RECEIVING TUBES, MINIATURE TUBES, SUB-MINIATURE TUBES
  PLANTS: OWENSBORO, KY.; TELL CITY, IND.; HUNTINGBURG, IND.; ANNISTON, ALA.
- CATHODE RAY TUBES
  GENERAL MANAGER
  ROBERT E. LEE
  PRODUCTS: TV PICTURE TUBES, INDUSTRIAL AND MILITARY CATHODE RAY TUBES, TUNGAR BULBS
  PLANTS: SYRACUSE, N. Y.; BUFFALO, N. Y.
- INDUSTRIAL AND TRANSMITTING TUBES
  GENERAL MANAGER
  ROBERT O. BULLARD
  PRODUCTS: INDUSTRIAL TUBES, TRANSMITTING TUBES, POWER ELECTRONICS EQUIPMENT
  PLANTS: SCHENECTADY, N. Y.; SCRANTON, PA.

GOVERNMENT EQUIPMENT DEPARTMENT
GENERAL MANAGER
GEORGE F. METCALF

- HEAVY MILITARY ELECTRONIC EQUIPMENT
  GENERAL MANAGER
  JOHN J. FARRELL
  PRODUCTS: MILITARY ELECTRONIC EQUIPMENT
  PLANT: SYRACUSE, N. Y.
- LIGHT MILITARY ELECTRONIC EQUIPMENT
  GENERAL MANAGER
  HERMAN F. KONIG
  PRODUCTS: MILITARY ELECTRONIC EQUIPMENT
  PLANT: UTICA, N. Y.

COMMERCIAL EQUIPMENT DEPARTMENT
GENERAL MANAGER
WILLIAM J. MORLOCK

- BROADCAST EQUIPMENT
  GENERAL MANAGER
  PAUL L. CHAMBERLAIN
  PRODUCTS: RADIO-TV STUDIO, RADIO-TV TRANSMITTER, RELAY EQUIPMENT AND ANTENNAS
  PLANT: SYRACUSE, N. Y.
- GERMANIUM PRODUCTS
  GENERAL MANAGER
  H. BRAINARD FANCHER
  PRODUCTS: GERMANIUM DIODES, TRANSISTORS, GERMANIUM RECTIFIERS, QUARTZ CRYSTALS
  PLANT: CLYDE, N. Y.
- COMMUNICATION EQUIPMENT
  GENERAL MANAGER
  HARRISON VAN AKEN
  PRODUCTS: TWO-WAY RADIO, MICROWAVE, CARRIER CURRENT EQUIPMENT
  PLANTS: SYRACUSE, N. Y.; UTICA, N. Y.

(IN TUBE AND GOVERNMENT EQUIPMENT, MARKETING IS PERFORMED AT DEPARTMENT LEVEL WITH ALL OTHER FUNCTIONS THE RESPONSIBILITY OF THE GENERAL MANAGERS OF THE PRODUCT SEGMENTS)

GE's Radio-Electronic Milestones

Significant dates and events over the last 75 years that portray the growth of this great electronic industry

1875 *Elihu Thompson (GE founder) transmitted and received wireless signals*

1878 *Edison Electric Light Co. (GE's parent co.) formed*

1880 *Edison gets basic patent on his lamp*
Edison United Mfg. Co. formed

1883 *Thomas A. Edison, a founder of GE, makes first real electron tube*

1885 *Edison's "Black Box" induction experiments*

1889 *Edison General Electric Co. formed*

1892 *GE formed thru combination of Edison General Electric and Thomson-Houston Cos.*

1897 *Frank J. Sprague operates first multiple unit controls for railways*

1898 *Elihu Thompson develops constant current transformer*

1900 *General Electric Research Lab. established*

1904 *Whitney develops electric resistance furnace*

1905 *Steinmetz develops high voltage rectifier*

1906 *Alexanderson introduces high frequency alternator*

1910 *First practical electric ranges*

1913 *Langmuir develops high vacuum, high voltage tube*
Langmuir suggests grid to control arc in mercury tube
Experiments with thoriated filaments

1916 *Navy operates a-c operated radio-telephone transmitter*
Development of tungar rectifier
Langmuir develops high-vacuum, mercury-vapor pump
15 MC generated with vacuum tube oscillators

1917 *First 200 KW Alexanderson high frequency alternator*
Development of dynatron & plio-dynatron

1918 *Getters improve vacuum tube manufacturing methods*
Production of tubes, transmitters and receivers for military in WW I

1919 *Work starts on water-cooler radio transmitting tube*
Genl. Engineering Lab. formed

1920 *Radio Dept. formed in Schenectady*

1921 *Thoriated tungsten filaments in radio power tubes*

1922 *First commercial power line carrier current equipment*
First radio receiver in Pullman railroadcars
WGY goes on air
Pallophoto phone—forerunner of modern sound-on-film

1923 *Development of superheterodyne and reflex circuits*
First airmail plane radio communication
Steinmetz dies
Photo electric relay principle demonstrated

1924 *KGO, Oakland, Calif. goes on air, 2nd GE Station*
Magnetron developed

1925 *Screen Grid tube developed by Hull*
Development of glow discharge regulator tube
Rectifier tubes (UX-213) eliminate "B" batteries
WGY first to use crystal control of carrier frequency
First front to rear R.R. communication
First commercial 50 KW AM transmitter
Caesium coated electrode photoelectric tube

1928 *WGY broadcasts first "remote" TV program*
Photoelectric cells applied to talking movies
Hull develops thyratron and phanotron
Carboloy Co. formed
First commercial 100 KW broadcast transmitting tube

1929 *First 50 KW AM broadcast transmitter employing low level modulation and class B linear r-f amplification*
Thyratrons control lights in Chicago

1930 *First 200 KW AM broadcasting transmitter*
High frequency cooking
TV projected on seven foot screen
Photoelectric relays used in industry

1931 *Sonic locator developed (acoustic radar)*
First automatic steering for aircraft
First long distance talking on light beams
Shield-grid thyratron developed

1933 *Metal tubes for industrial applications*
First 80,000 volt X Ray equipment

1934 *300-kw sealed tube frequency changer*

1935 *Metal tubes for home radios*
Development of "memory" oscillograph
Development of Alnico magnetic material
Quantity production of small high vacuum switches

1936 *Velocity modulation tube produces cm frequencies*
Sealed ignitrons used commercially

1937 *First application of radio communication on fireboats*
R-F single ended pentodes

1938 *1,000,000 volt X Ray*
Develop soldered-can tube technique

1939 *Radio & Television (later Electronics) Dept. formed*

1940 *Disk triode "Lighthouse" tube announced*
First TV network service—N.Y.C. to Schenectady area
Color TV demonstrated at Alexanderson's home

1941 *First STL links for FM broadcasting*
Production started on air search radar
W2XB (now WRGB) highest-powered TV station

1942 *Light house tubes used in Radar*

1943 *Large Scale manufacture of industrial heating*

1944 *First time FM applied to power line carrier current*
First commercial electron difraction instrument

1945 *First commercial radar*
Electronic navigator for ships
Variable reluctance pickup

1946 *Aluminized-back TV picture tubes*
Pulsed light system for TV film projection

1947 *First 2,000 MC commercial microwave relay system*
Development of dyotron microwave tube

1948 *Electronic Park, Syracuse in operation*
FM Receivers used in buses
Single sideband selector for crowded radio bands
Portable radio with rechangeable batteries

1949 *First binary scaler type TV sync generator*
Germanium diodes in mass production
First demonstration of narrow-band mobile radio

1950 *First radio-activity detectors produced to MIL specs*
Dome origniates frequency interlace color TV
One millionth clock radio manufactured
TV effects produced electronically

1951 *First high gain side-fire helical antennas for UHF-TV*
Junction transistors and germanium diodes
Installed largest privately owned microwave relay
Radar systems for continental defense
Radar mass produced for jet planes
Advanced electronics department laboratory established by GE at Cornell U.

1952 *35 KW VHF TV transmitter*
Microwave radio links protect public utility exchange
Facilities expanded at Electronics Park

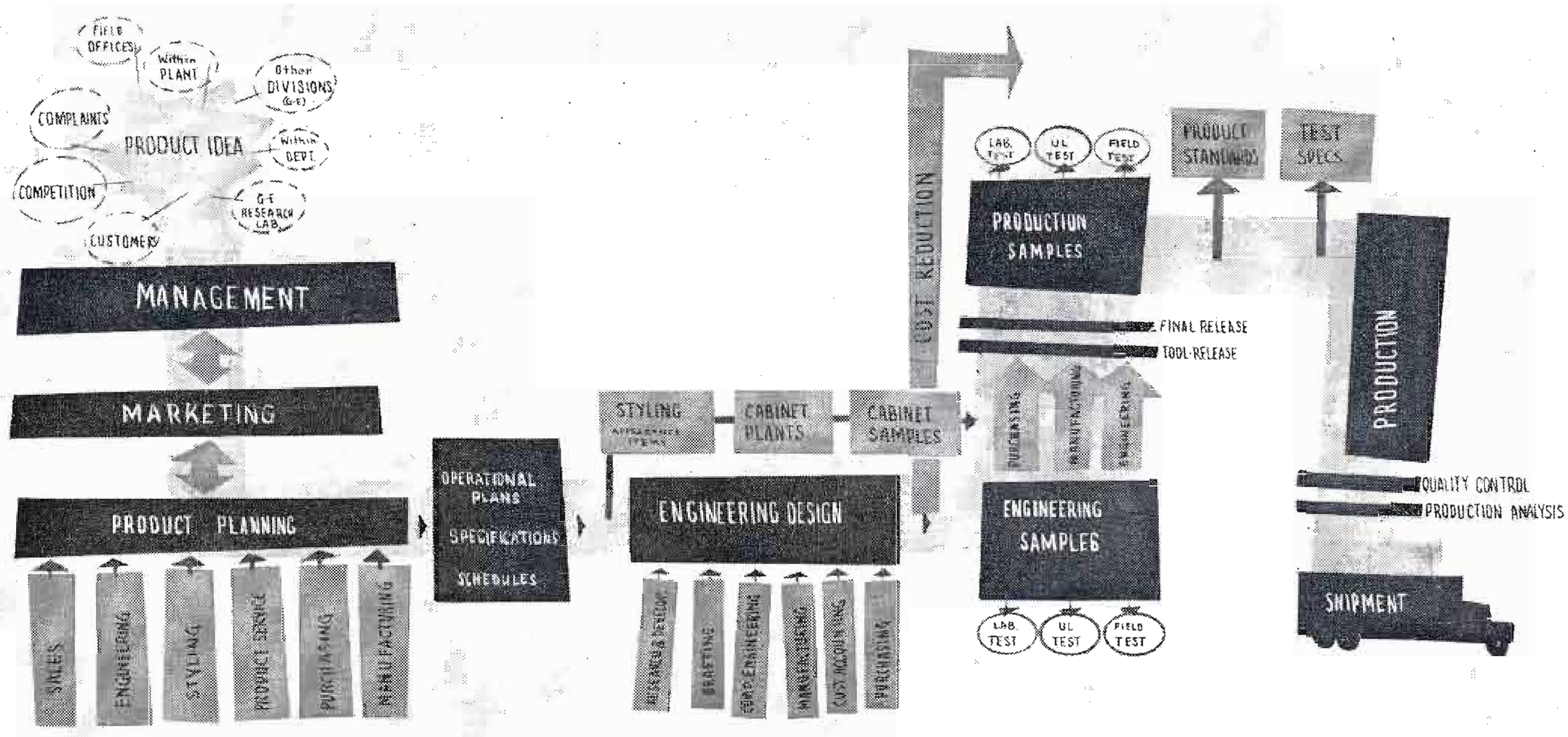
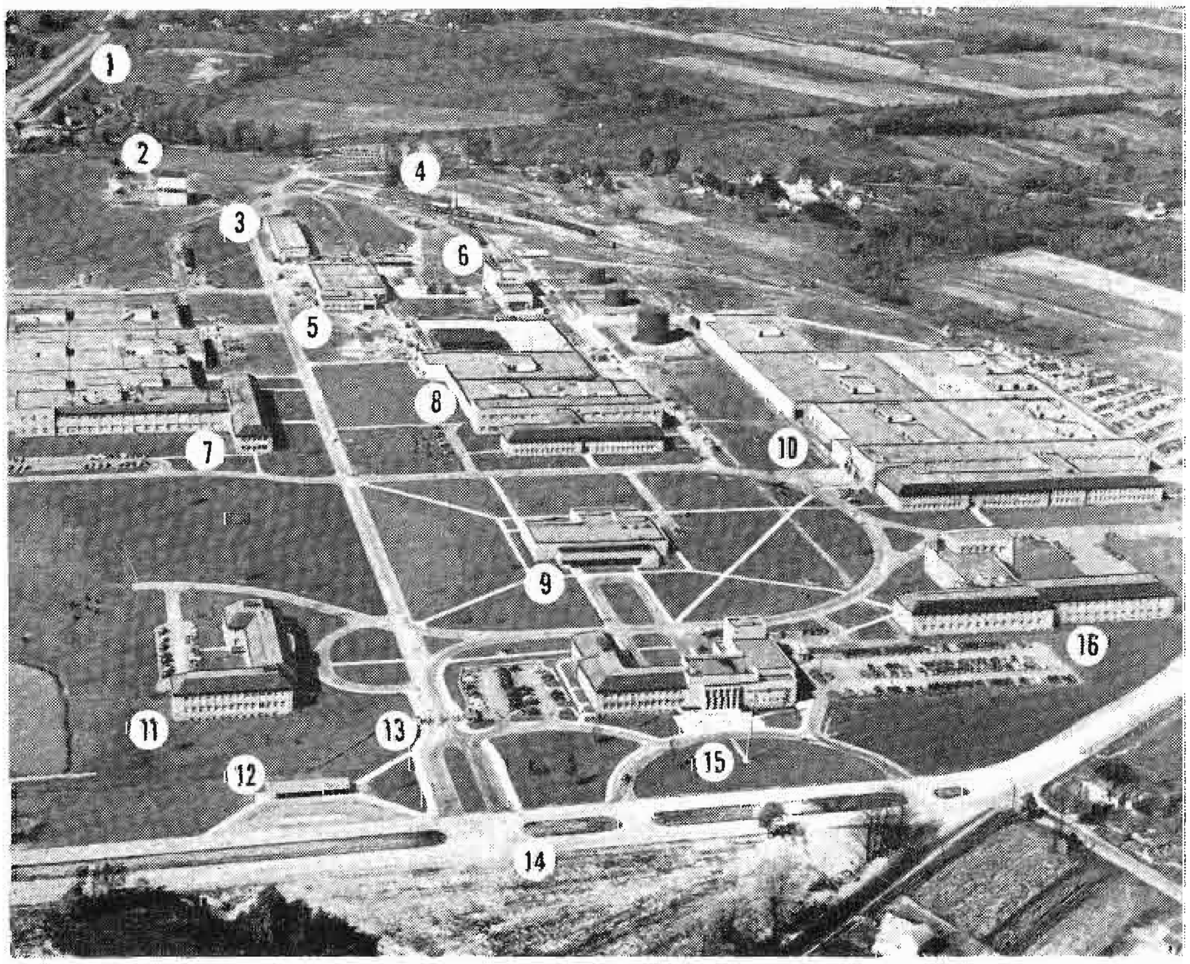


Fig. 4: Flow chart for electronic products depicts the steps a new product goes through from the idea to the end-item stage and graphically illustrates the great amount of planning and preparation needed before actual mass production can be effected.

and unity of purpose—for a wise mind and a strong hand to command diffused and uncoordinated policies. This need was met in 1892 when the Edison General Electric and Thomson-Houston companies were merged to form the General Electric Co. under the leadership of Charles A. Coffin.

It is evident that the initial organizational and business activities were focused primarily about the electrical power field. However, some of the company's research activities prior to World War I can now be viewed as forming early milestones in the development of GE's present-day electronic activities. Steinmetz's high voltage rectifier, Alexanderson's high frequency alternator and Langmuir's vacuum tube space-charge research are examples in this connection. Page 101 lists some of the milestones that contributed to G.E.'s electronic progress.

Fig. 5: Aerial photo of GE's electronic headquarters shows (1) New York State Thruway, (2) engineering test building, (3) engineering building, (4) small warehouse, (5) service building, (6) power house, (7) Commercial & Government Equipment Dept., (8) Cathode Ray Tube Plant, (9) Restaurant, (10) Radio & Television Dept., (11) Administration Bldg., (12) bus stations, (13) main gate, (14) parkway, (15) Reception Building, also includes: auditorium, employee relations, main dispensary, (16) electronic laboratory.



Anticipating the rapid expansion of the electronics industry following World War II, General Electric has invested about $75 million in construction of the finest possible electronics research and production facilities. Today, Electronics Park in Syracuse, N.Y., headed by vice-president Dr. W. R. G. Baker, is the administrative hub of a wheel of some 18 manufacturing plants in the Electronics Division (Fig. 2). The division employs about 31,000 people, of which 1313 are engineers.

Organizational Structure

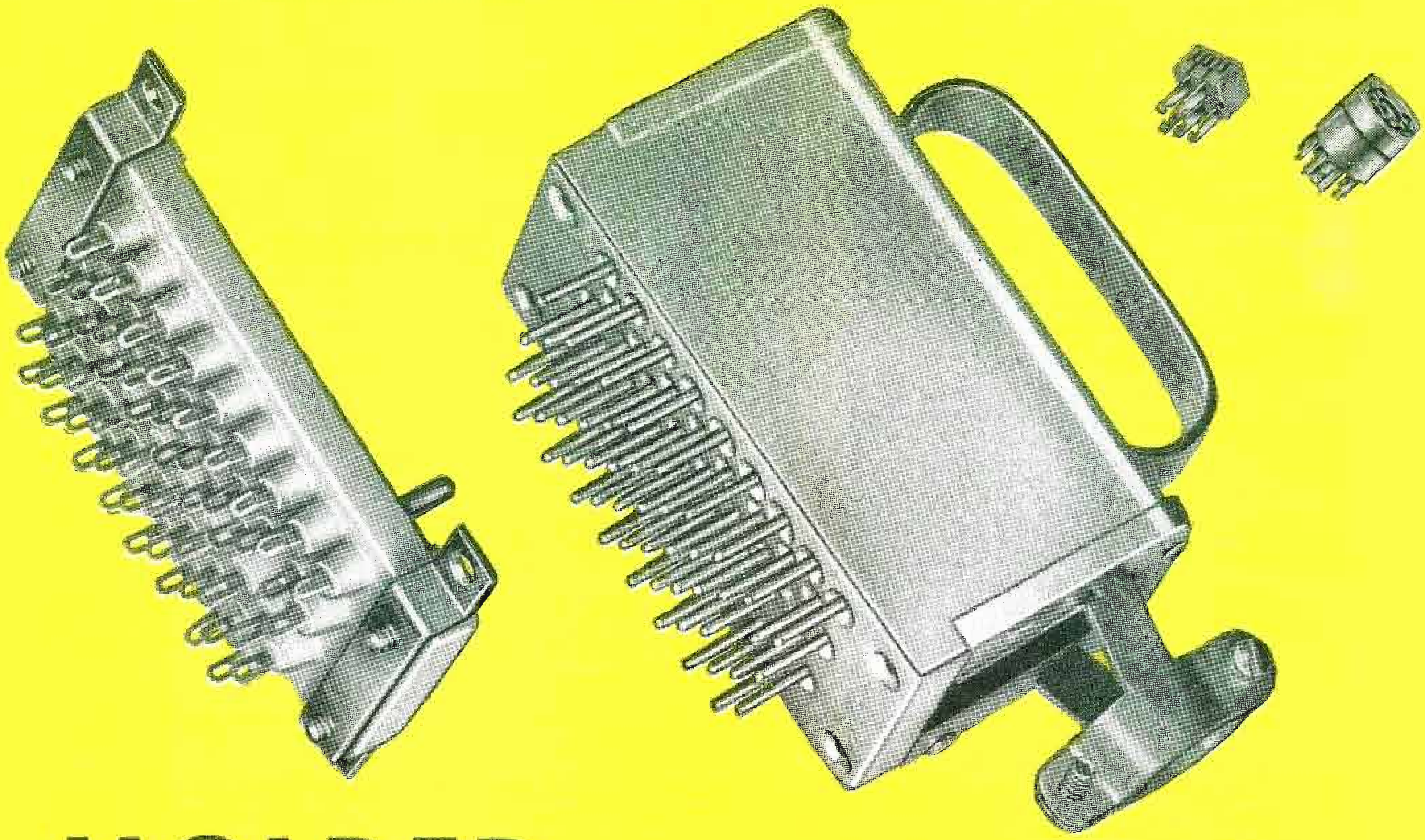
Fig. 3 shows the organizational structure of the Electronics Division and the major product lines of its departments. The Electronics Division is one of 28 operating components of the Company.

Sales billed by the Electronics Division since the Park has been in operation have been increased by some 260%.

Planning for Electronics Park started in 1942 just after World War II began. Construction got under way in September, 1945, and by early 1948 all the main buildings were in operation. Fig. 5 identifies the buildings at this electronic headquarters, while table (p. 98) provides interesting statistical data.

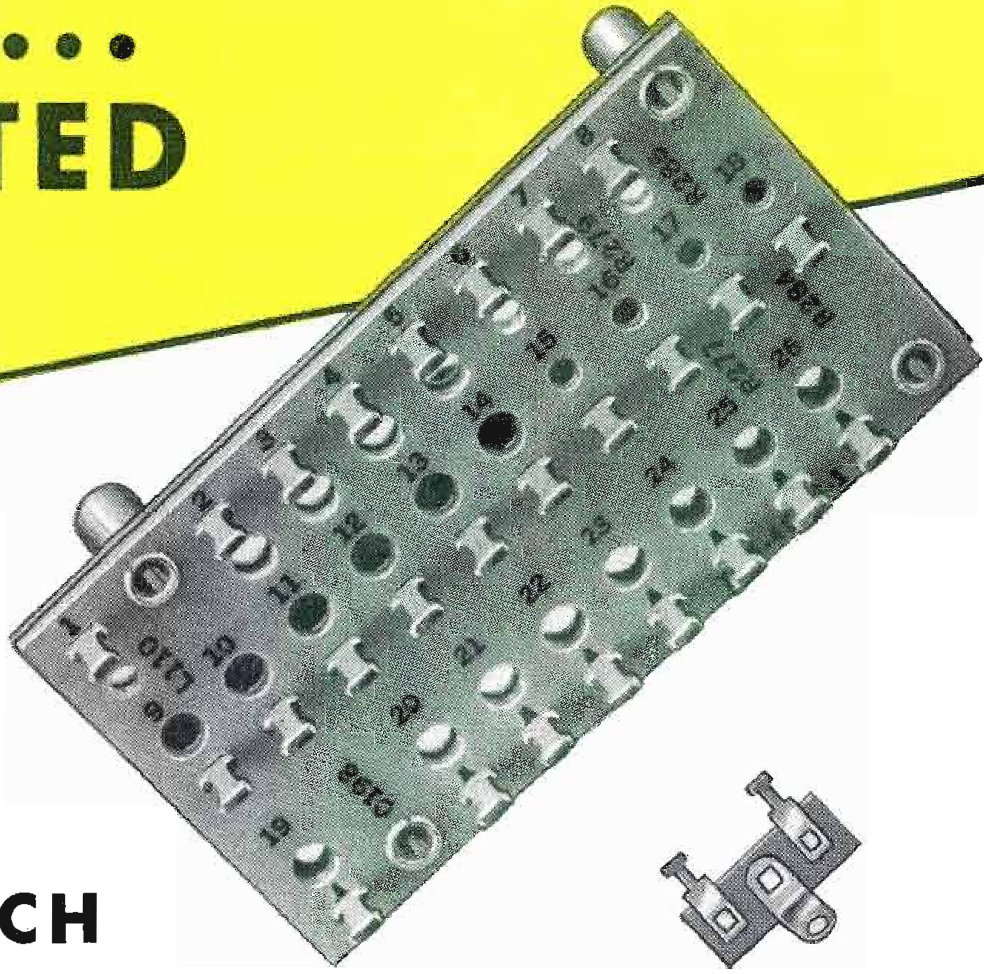
From time to time interested readers have requested information as to how the decision to manufacture

(*Continued on page* 137)



MOLDED... LAMINATED

METAL PLASTIC ASSEMBLIES



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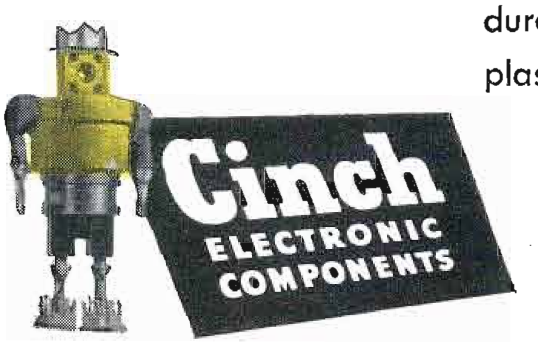
Cinch Electronic Components are available at leading jobbers — everywhere

The wide demand and long use of Cinch components is testimony to engineering vision and design . . . to the exactitude demanded in the manufacture and the appropriateness and durability of the materials. Whatever the requirement for metal plastic assemblies, Consult CINCH.



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WASHINGTON
News Letter

Latest Radio and Communications News Developments Summarized by TELE-TECH's Washington Bureau

NEW MILESTONE—With the color television demonstrations of the compatible system devised and approved by the highly competent National Television System Committee, headed by Dr. W. R. G. Baker who is the veteran General Electric Vice President in charge of electronics, staged before the Federal Communications Commission in New York on Oct. 15, a new milestone in the progress of U.S. television was achieved. There is no question that the relatively few and insignificant statements of opposition to the adoption of the NTSC compatible color TV system, which have been filed with the FCC, have produced no basis for hearings on the NTSC blueprint.

SPEEDY APPROVAL—With the united front of the outstanding engineering leadership of the electronics-radio-television industry, in their formulation of the NTSC system and comprehensive report, the FCC has pledged concentrated and expeditious sanction of the NTSC compatible color television system—possibly by Christmas or by the first of next year. After the FCC approval the manufacturing industry, particularly the companies which have been leaders in the establishment of the compatible system will center every effort to launch the huge task of mass production of color video receivers. But naturally there will have to be a period of time to produce receivers at mass market levels of cost.

SUBSCRIPTION TV—Because subscription or fee television would mean such a revolutionary or fundamental method in the American system of broadcasting, the FCC leadership is regarded as united on the premise that Congress should determine this policy to guide the Commission. There is already one measure before Congress—the proposal of Rep. Carl Hinshaw, California Republican, who introduced a bill at the last session which would redefine the term "broadcasting" in the Communications Act to make subscription TV and theater TV a common carrier type of service. The Hinshaw measure which was referred to the House Interstate Commerce Committee poses the drastic change in the concept of regulation of broadcasting and television to place these two proposed services in television in the category of common carrier like telephone and telegraph.

FM FREQUENCIES—FM broadcasters were recently warned by FCC Commissioner E. M. Webster that their frequencies may well be vulnerable to petitions, particularly from frequency-starved services in the mobile radio field which are experiencing extreme conditions of congestion and need for additional spectrum space. Commissioner Webster advised the FM broadcasters that, if there is not increased utilization of the FM frequencies, particularly in the 88-108 megacycle band, FM broadcasting will be in an untenable position to justifying its right to retain all the frequencies allocated to it. The situation recalls the controversy on mobile radio service assignment in the 72-76 megacycle band between two television channels. Multiplexing of FM signals may be the answer for that field of broadcasting, it has been proposed by Commissioners George E. Sterling and Webster, the two FCC engineering members.

PETROLEUM RADIO—Expansion of mobile and microwave communications by the petroleum industry is under study at the November 11 meeting of the American Petroleum Institute's Central Committee on Radio Facilities in Chicago. Among the subjects for consideration are the conclusion of a possible substitution of FM broadcast facilities in the 104-108 MC band for the 72-76 MC frequencies for fixed communications; the proposed establishment of an inter-industry Microwave Frequency Coordinating Council; planning for the use of assignments in the 450 MC band after the FCC proceeding on that spectrum portion; use of the 2000-2850 basic frequencies in mobile radiotelephony in the maritime radio spectrum space; study of the FCC proposal regarding frequencies above 890 MC extension of presently used Shoran frequencies; and new developments in the radiolocation service and mobile relay operation. The central committee also is to study the proposal of Petroleum Communications, Inc., which has requested FCC approval for a group of Louisiana companies engaged in the petroleum and allied fields to establish a non-profit large-scale radiocommunications network.

OPPOSE FINES PLAN—A number of major groups in the mobile radio field have presented opposition to the Senate and House Interstate Commerce Committees on the FCC-sponsored legislative proposal to give the Commission authority to impose small civil penalties in the form of $100 fines for violation of its rules and regulations by all non-broadcast services. Statements of opposition went to the two Congressional committees from the American Taxicab Association, National Bus Communications, The American Trucking Associations, The American Automobile Association, Aeronautical Radio, Inc., and a member of airlines.

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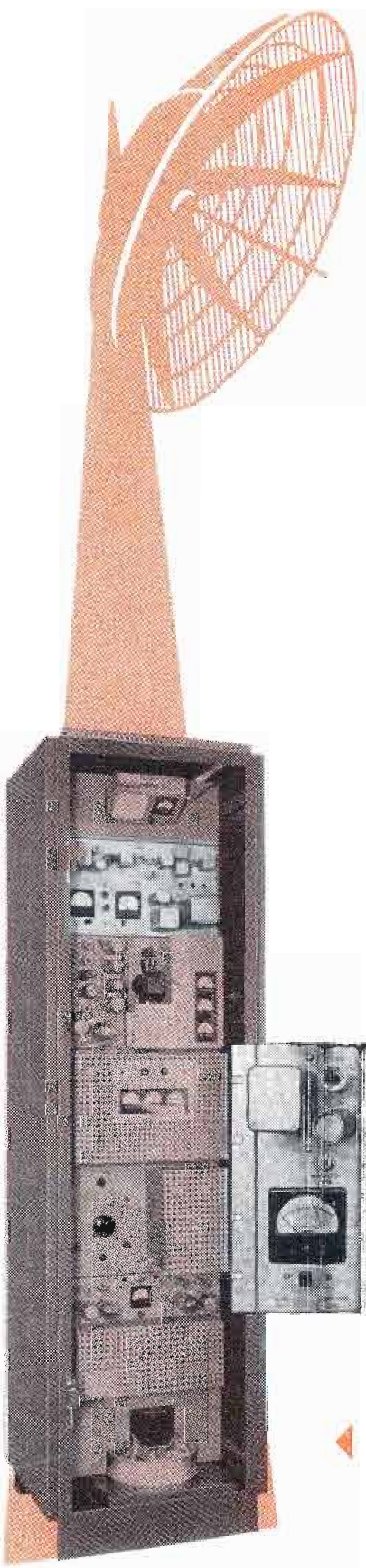
Washington, D. C.

ROLAND C. DAVIES
Washington, Editor

RAYTHEON

first again with the finest in television microwave



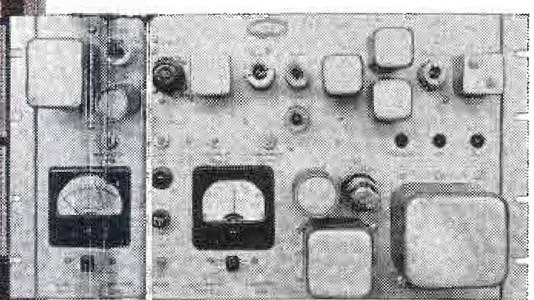
Magnalink 2000 mc

now meets full FCC specifications for STL

— 15,000 cycles audio frequency response

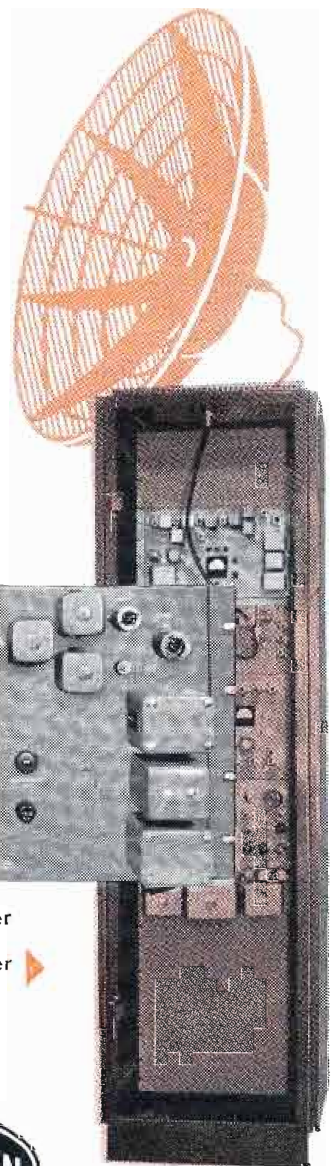
— 55 db signal to noise ratio

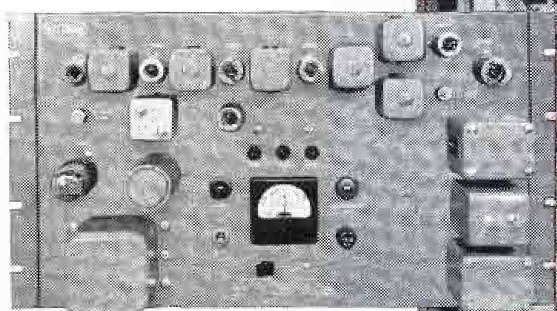
The first multiplexed audio-video equipment to meet full FCC specifications for STL, Raytheon Magnalink, because of its high power, also permits flexibility through the use of 100 ft. of RG-14U for normal applications, difficult remotes or STL. Combinations of RG-14U and 7/8″ coax may be used for greater height between the equipment, housed indoors, and the parabola (no limitations on length of coax at receiver installation). Passive reflectors may be omitted for normal installations, thus eliminating their cost, but may be used where maximum radiated power is required.



Sound Subcarrier Transmitter

MTR 50 Microwave Transmitter





Sound Subcarrier Receiver

MTR 50 Microwave Receiver

Specifications and FCC Filing Data Available

Write for full information

Magnalink 50 watt power and the superiority of 2000 mc propagation characteristics permit spanning greater distances than previously thought possible. Greater fade protection, simplified all channel field tuning and polarization change merely by rotating feed are but a few of the advantages offered by Raytheon's powerful Magnalink equipment — specifically designed for industry's STL, inter-city and long distance remotes. For the right equipment to fill your microwave requirements, for economy and operating convenience, investigate Raytheon's complete line of microwave equipment.

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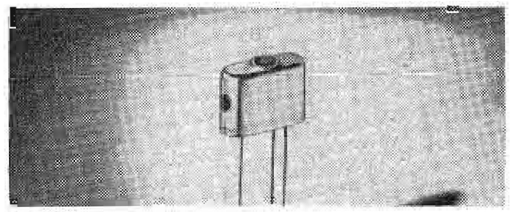
Dept. 6270-TL

WALTHAM 54, MASSACHUSETTS

PHOTO TRANSISTOR

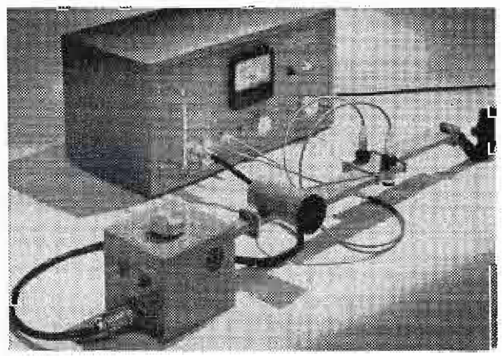
Said to be the first commercially available photo amplifying transistor made, the germanium, n-p-n junction Type X-25, is available for immediate



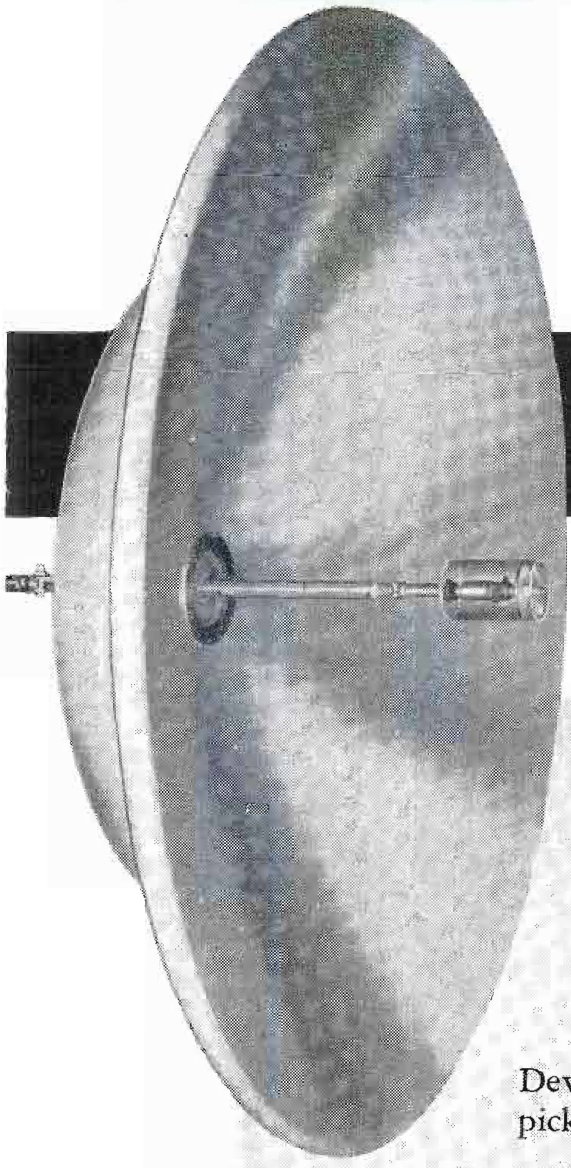
application in automatic punch-card machines, automobile dimmers and TV receiver brilliance controls. Power is in the order of 60 milliwatts. If a mechanical or electro-mechanical chopper is used, the unit can be coupled with an ac amplifier to supply a pulsed signal for ac current flow. Experiment has shown responsiveness to frequencies as high as 25 KC. The photosensitive unit is housed in a heat and moisture resistant 17/32 x 5/16 x 3/16 in. case. Two 0.093 in. diam. pins on 11/32 in. centers fitted with 0.015 in. diam. nickel wire leads are attached to the case. The 3/16 x 11/32 in. light-sensitive face is on the side opposite. **Transistor Products, Inc., Clevite Corp. operating unit, Snow and Union Sts., Boston 35, Mass.**—TELE-TECH & ELECTRONIC INDUSTRIES.

VSWR METER

Model 110A CTI X-band, a voltage standing wave ratio indicator, includes an oscillator; a forward and reversed directional coupler, with bolometer take-offs for source and reflected



power; and, a direct-reading ratiometer with dual scales calibrated directly in VSWR—1.06 to 1.3 and 1.3 to 2.5. Continuous coverage of the frequency band overcomes missing points. Beyond an increase in operating speed, there is no probe or slot error, no readjustment for frequency changes, and no change in reading affected by changes in r-f power. Specifications are: r-f power source, V 260 klystron; wavemeter accuracy approx. ±1 MC; overall accuracy within 2%; coupler directivity, greater than 35 db; primary power, 115 v., 60 cps; output waveguide fitting, UG-39/U; main cabinet, 10½ x 20⅝ x 10⅜ in.; overall waveguide assembly, 34 in.; weight, 40 lbs. **Color Television Inc., 1000 E. San Carlos Ave., San Carlos, Calif.**—TELE-TECH & ELECTRONIC INDUSTRIES.



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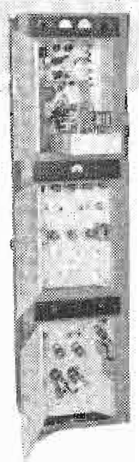
Federal's FTL-27C

MICROWAVE RELAY LINK

. . . the most widely accepted system for the relaying of video signals

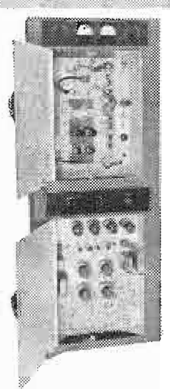
Developed specifically for studio-transmitter links, inter-city relays and remote pick-up service, Federal's FTL-27C provides design features of the highest order.

Among these outstanding features are: Automatic unattended operation . . . immediate on-air operation . . . self-contained test circuits . . . and numerous other facilities for *dependable* operation and *simplified* maintenance.



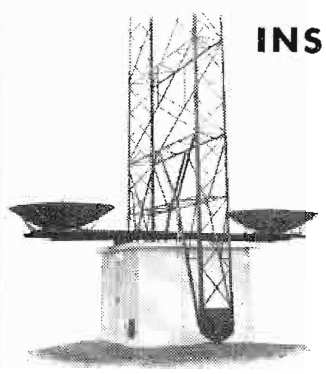
TRANSMITTER

- Direct frequency modulated
- Reflex klystron power oscillator
- 5 watts *minimum* power output
- Crystal controlled
- Built-in wavemeter, r-f power measuring devices and local monitoring facilities
- Internal receiver for off-air monitoring



RECEIVER

- Single superheterodyne type
- Crystal controlled
- Double tuned preselector
- Wide frequency response
- High signal to noise ratio
- Constant video level over wide range of input signals



INSTALLATION

- Circular parabolic antenna for both receiver and transmitter
- Antenna may be ground-mounted for use with tower-mounted reflectors
- Provides stable klystron operation and simplifies maintenance
- Reduces transmission line costs

SOUND CHANNEL

- Exclusive FTL development
- Allows simultaneous transmission of audio and video over TV link
- Eliminates need for leasing high-quality telephone lines
- Fully self-contained

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DIVISION OF IT&T

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In Canada: Federal Electric Manufacturing Company, Ltd., Montreal, P.Q.

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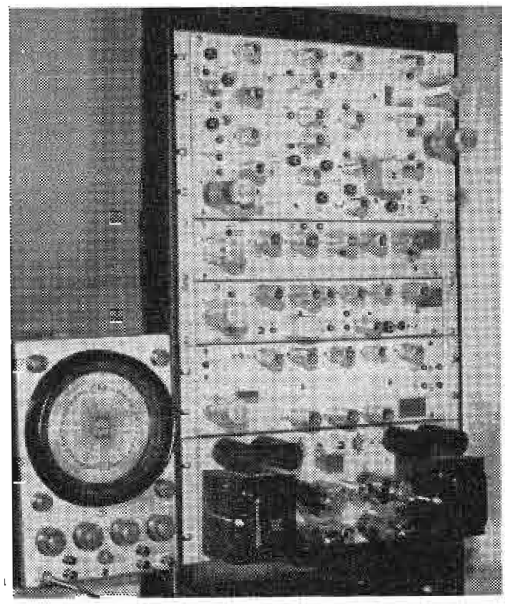
COLOR TV TESTER

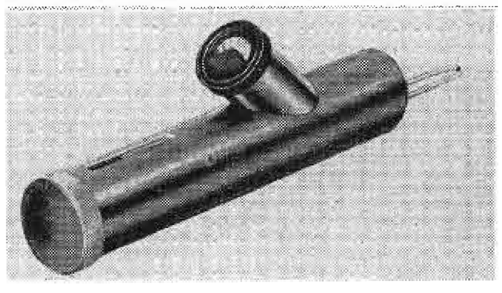
The 1601-AR color TV testing instrument is designed to measure the performance, alignment, and phase errors of color TV equipment. Operating



from a composite NTSC signal, presentation is in the form of an instantaneous vector plot of the colors and their amplitudes displayed by a transparent overlay (calibrated in degrees and amplitude) on a 7-in. CRT. The unit includes decoding amplifiers, quadrature switching circuits, phase delay circuits, local subcarrier amplifiers, a color subcarrier generator, a sync separator and field trigger, a 30 cycle square wave generator, a 90° marker generator, a reference oscillator, and a regulated power supply. The calibrated chart on the cathode ray tube face enables setting standard values of the major saturated colors and also indicates the burst amplitude and phase. **Telechrome, Inc., 88 Merrick Rd., Amityville, L. I., N. Y.**—TELE-TECH & ELECTRONIC INDUSTRIES.

UHF WAVEMETER

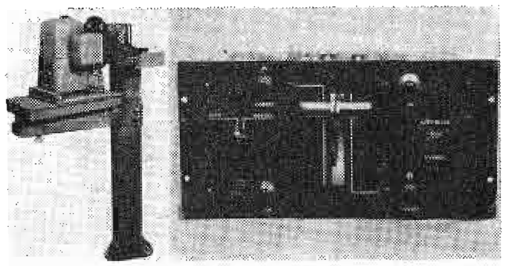
Model U-3 UHF wavemeter is specifically designed for the UHF-TV band. Covering a range from 400 to 1,000 MC, it provides a considerable overlap in



frequency spectrum from the nominal 470-890 band allocated for this service. Coupling to the wavemeter tuning element is facilitated by the use of an external coupling loop designed to enable easy access to the portion of the circuit under examination. The absorption circuit consists of a high Q resonant cavity that is tuned by a slug-type split stator capacitor. **Linear Equipment Laboratories, Inc., Brightwater Pl., Massapequa, N. Y.**—TELE-TECH & ELECTRONIC INDUSTRIES.

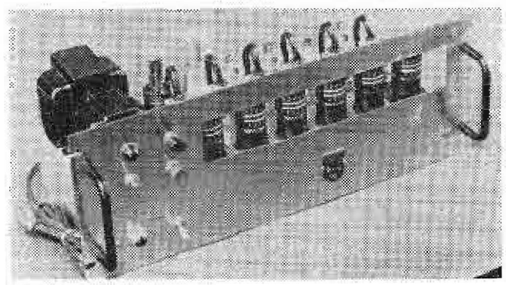
MULTIPLEXER

The new Gray moving mirror multiplexer combines three sources of optical projection in a single TV film camera without image distortion. A slight shift of the mirrors opens a space so that a third projector can be mounted, just behind the point where the mirrors converge at right angles, and focused on the "mosaic" in the camera. "Keystoning" and other distortions caused by projecting over the tops of multiplexer mirrors are thus eliminated. Actuated by a motor drive, the moving mirror multiplexer can be remotely controlled to open and close in less than a second. The "Telojector" (left), used for projecting standard 2 x 2 in. slides, is shown as it would be positioned to project between the multiplexer mirrors. The 5¼ x 11 in. manual control box (right) can be mounted in a standard RCA console to control a remote "Telojector." **Gray Research and Development Co. Inc., 658 Hilliard, Manchester, Conn.**—TELE-TECH & ELECTRONIC INDUSTRIES.

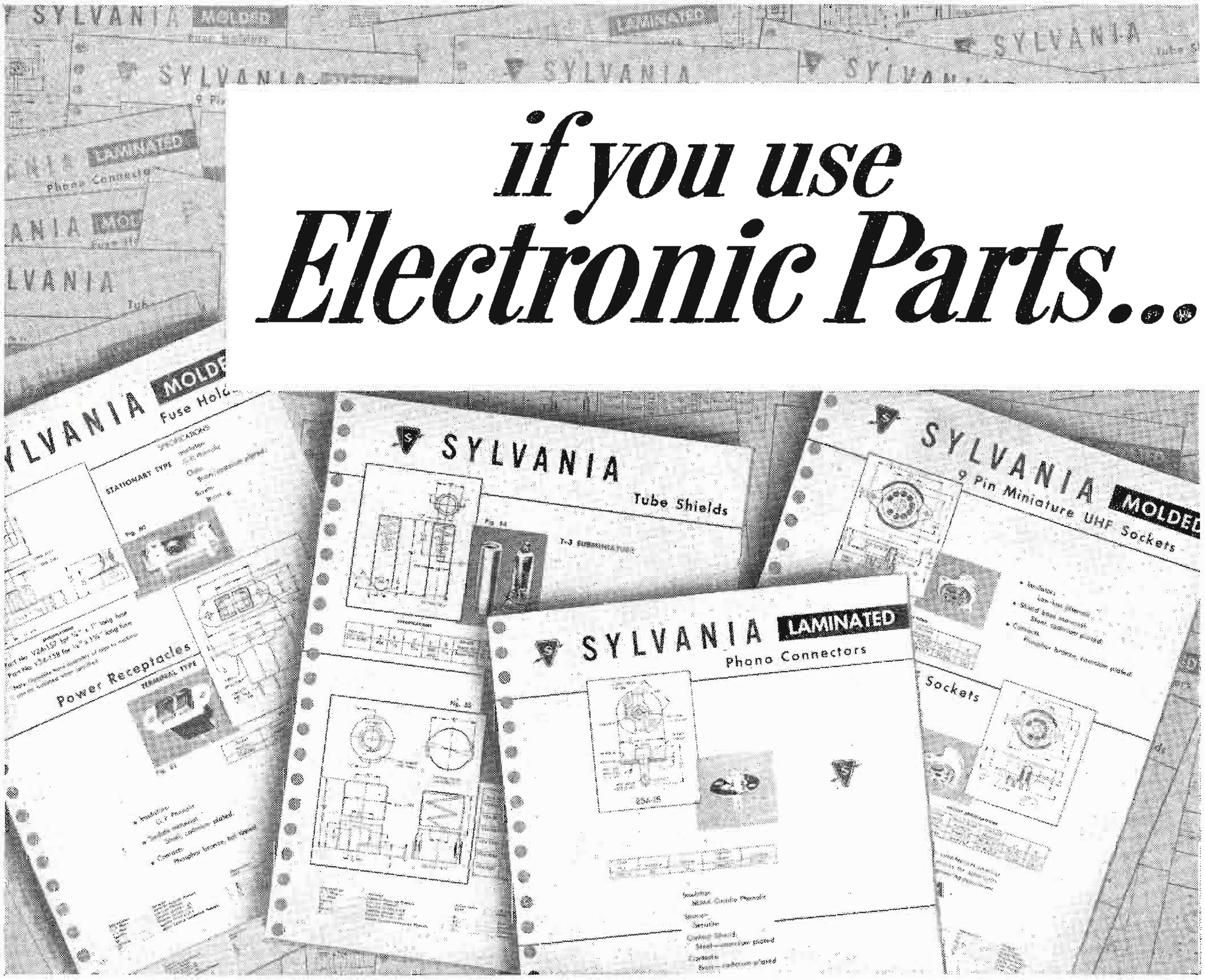


DECADE SCALER

A new high-speed, six-digit, decade scaler, adapted for use in telecommunication and frequency and nuclear measurement computers, includes a power supply and appropriate control circuits. It has a maximum cyclic rate of 30,000 events/sec., a minimum resolving time of 25 μsecs, and a total registration of 999,999. Power is taken from any 95-130 v., 50-60 cps circuit. The input circuit uses an adjustable-sensitivity Schmitt trigger. As the circuit responds to changes in input level, it is not limited to a specific input wave shape. Sine waves of 1 v. rms can be counted at speeds of 5/sec to 30,000/sec. Pulses at any rate below 30,000/sec. are accepted. Each decade includes one E1T counting tube and one 5964 pulse-shaping tube. Power supply and signal-handling are on the main chassis. These circuits include three 5964 tubes, one 6AL5, and one 5Y3GT. **North American Philips Co., Research and Control Instruments Div., 750 South Fulton Ave., Mount Vernon, N. Y.**—TELE-TECH & ELECTRONIC INDUSTRIES.



if you use Electronic Parts...



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CUES for BROADCASTERS

(*Continued from page* 91)

sockets are mounted on the chassis to accommodate the XL-12 plugs from the Magnecord switcher. The cables that run from the switcher to each recorder are plugged into these sockets. The cable from the switcher to the Recorder input on the amplifier is left in place.

Three, shielded, two conductor microphone cables are run through grommets and connected as shown in the diagram for the two recorders and amplifier microphone input. These are terminated with Cannon XL-12 male plugs. The shields are grounded to the 3x5 in. chassis, so a common ground is used throughout the system. The entire assembly is mounted on the PT6-HT panel to the left of the changeover switch.

Record Input Connection

In position "A", the recorders are connected to the record input of the amplifier in the usual way so normal recording or play back can be handled, depending on the setting of the function switch on the amplifier.

In position "B", the master tape is placed on #1 recorder, the blank tape is placed on recorder #2, the Magnecord PT6-HT switch is placed on position #2 for number two machine, and the function switch on the amplifier is placed in record position. Both machines are started and the information on tape #1 is recorded on tape #2.

In position "C", the master tape is placed on machine #2 and the blank tape on machine #1. The Magnecord switcher control is placed in #1 position, the amplifier again in record and the information on tape #2 is recorded on tape #1.

This duplicator has been useful for making duplicate tapes for other stations, various schools, etc. It is also ideal for editing and dubbing tapes.

Time Signal Generator

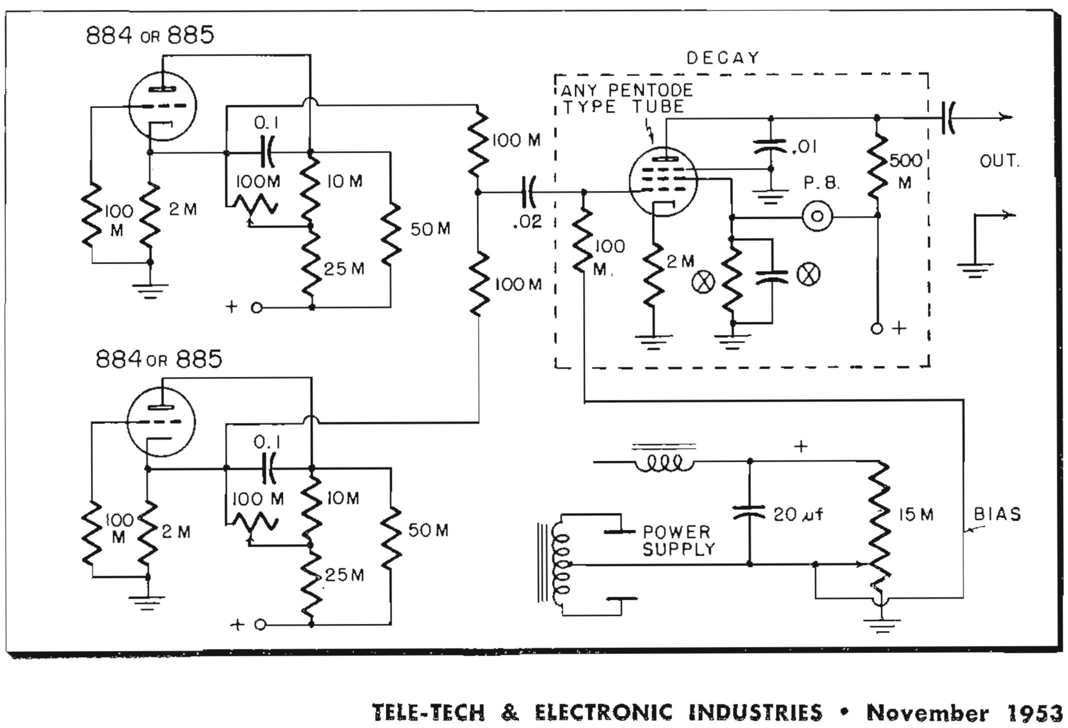
C. HARVEY HAAS, Chief Engineer, KSPA, Santa Paula, Calif.

FROM observation, it seems there are as many types of time signals as there are stations; some use hand chimes, some mechanical and some straight oscillators. A tone from an oscillator is usually "pure," but pure tones are not pleasing to the ear. At this station we use a combination of two tones, the result is pleasing, and in addition to this, the tone is always of the same duration.

Both oscillators generate a tone which is varied by changing the value of the 100M pot; a point will be found which is pleasing to the ear. These frequency combinations can cover a range, to suit the individual. The time of decay is determined by the resistor and condenser marked ⊗. A good starting value is approximately 100M for the resistor and approximately 0.5 for the capacitor. However this depends on the whims of the engineer. The push-button is pressed once for the signal. Duration button holddown has no effect on the decay.

No signal should pass through the decay tube until the button is pressed. Pressing this button puts a plus charge on the resistor-capacitor combination, also grid #2 of the tube. Thus the signal passes through. At the same time this combination is "bleeding off," during this period, the signal is starting to decay.

Circuit for producing combination tone in time signal generator



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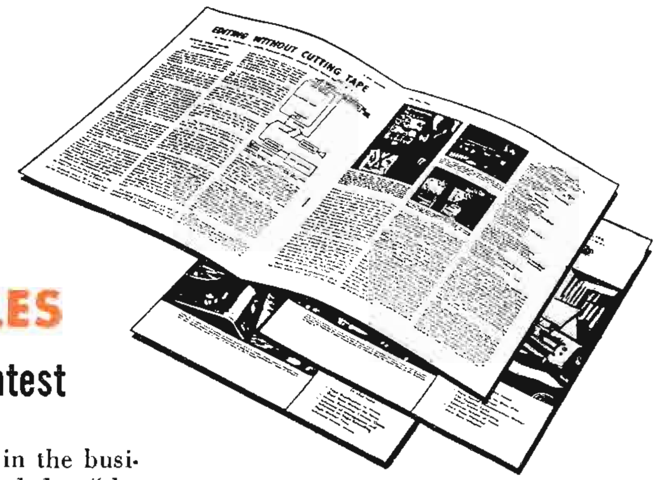


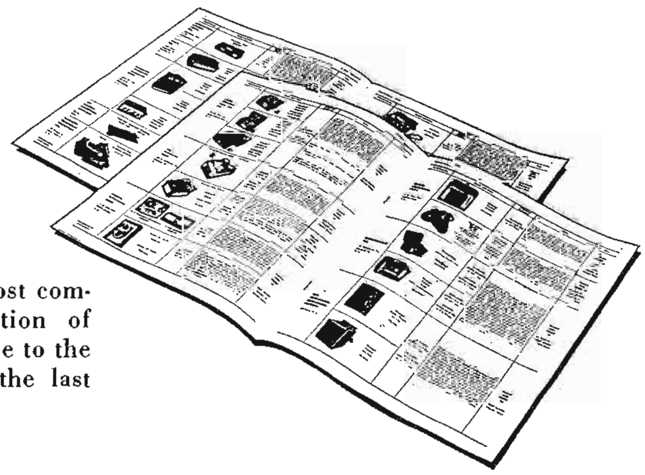
20 PRIZE-WINNING ARTICLES

from Audio's International Sound Recording Contest

Here's a wealth of new ideas on how to use tape and disc recordings to achieve greater economy and efficiency in radio, TV and sound studio operation.

With reference to these articles, one of the contest judges commented as follows: "I have never received so much information which was new and exciting in such a short time in all of my years in the business." And another judge stated that "the information and descriptions of recording operations conducted in small radio stations and recording studios throughout the country has been quite an education."

Contest winners include entries from 11 different States, as well as from Canada and Switzerland. The 20 best articles, which were awarded cash prizes totaling $1400, will be published in the pages of Audio Record. The information thus made available to the industry will be of real value to sound recordists everywhere.



QUICK FACTS ON MAGNETIC TAPE RECORDERS

Each year, Audio Record brings you a complete, up-to-date listing of all makes and models of tape recording machines —with conveniently arranged price and performance data. This directory issue, published in September, is the most complete and authoritative compilation of tape recorder information available to the industry. Over 75,000 copies of the last issue were distributed.

. . . plus many other articles of timely interest to the sound recordist

Audio Record keeps you well informed on all the latest trends and technical developments in all phases of tape and disc recording. It is not an advertising publication and its sole purpose is to render a needed and useful service to the industry.

Audio Record, published 8 times a year, is currently distributed free of charge to a request mailing list of about 35,000 sound recordists in broadcasting stations, recording studios, schools and colleges throughout the country.

IT'S YOURS FOR THE ASKING

A letter or post card will add your name to the Audio Record mailing list. And if you would like to have others in your organization read it also, send their names along, too. Just write to Audio Devices, Inc., using the Dept. No. listed below. All requests addressed to this Dept. will be started with the July-Aug., 1953 issue, so you will be sure to get *all* the prize-winning articles, as well as the 1953 Tape Recorder Directory Issue.

AUDIO DEVICES, Inc.

Dept. AR-4, 444 Madison Ave., New York, N. Y.

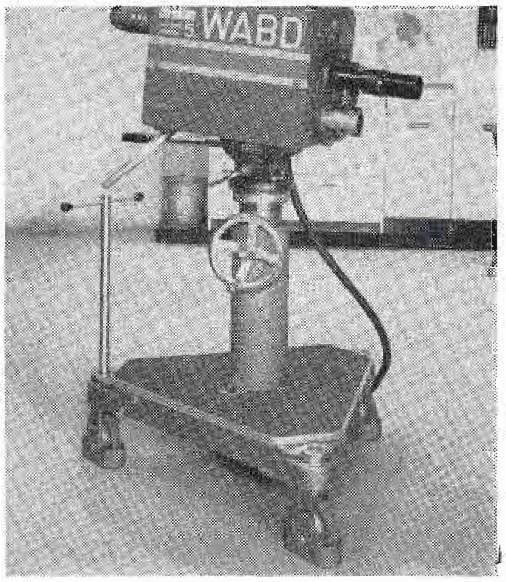
Export Dept.: 13 East 40th St., New York 16, N. Y., Cables "ARLAB"

THEY SPEAK FOR THEMSELVES

audiodiscs
audiotape
audiofilm
audiopoints

CAMERA DOLLY

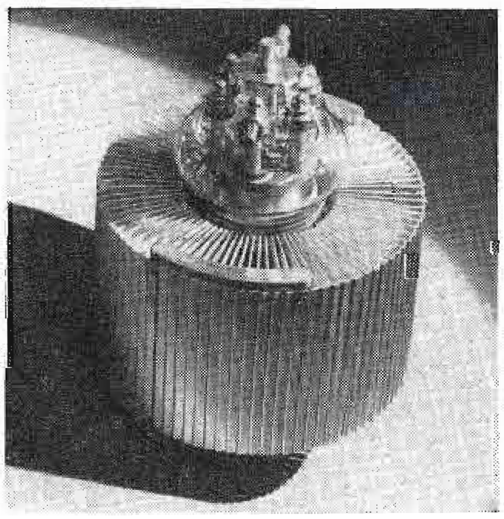
The new crank operated TV camera dolly shown is composed of two sections: a triangular three-wheel base



and a camera mounting column that weigh approximately 50 and 40 lbs., respectively. The unit is steered by the "T" handle which also locks the wheels in the desired stationary position. The camera is raised and lowered by a simple, silent-action wheel crank. The wheel guards are adjustable from 1/8 in. to 1 in. above floor level. **Allen B. DuMont Laboratories, Inc., Television Transmitter Div., 1500 Main Ave., Clifton, N. J.**—TELE-TECH & ELECTRONIC INDUSTRIES.

TRIODE

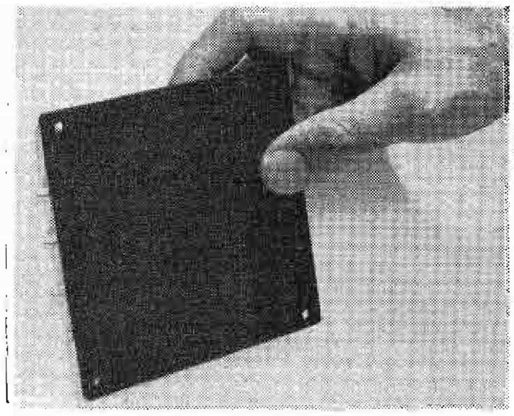
The ML-5531, a forced-air-cooled, heavy-duty triode for industrial use, incorporates a heavy wall anode, a thoriated tungsten filament, and electrode mountings and kovar seals. Operating at frequencies up to 30 MC, the unit meets the requirement for a single-tube oscillator in 15 kw output electronic heater service, and a single-tube, final-stage amplifier in 10 kw AM broadcast service. Max. ratings include 30 kw plate input; 10 kw plate



dissipation. Filament operates at 6.3 v., 92 amps. **Machlett Laboratories, Inc., 1063 Hope, Springdale, Conn.**—TELE-TECH & ELECTRONIC INDUSTRIES.

TRANSDUCER

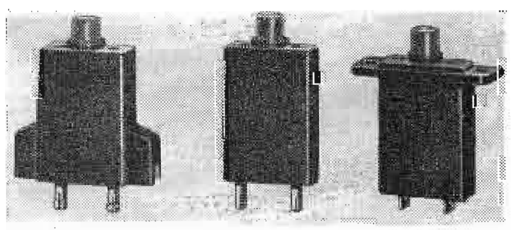
Model 200 heat-flow transducer can drive indicating or recording meters directly because of the high-linear electrical output relative to heat-flow gradient across the unit. High electrical output results from a large area-density of silver-constantan thermocouple junctions, the output from which can be connected to various physical and electrical configurations. Based on a 3/64 x 4½ x 4½ in. unit containing from 180 to 720 junctions, plus a thermocouple to check ambient temperature, the transducers have a range of sensitivities up to 6btu/ft.^{2}/hr./mv. Each transducer weighs approximately one ounce and has thermopile and thermocouple terminals brought out to one edge. Specific applications are total-hemispheric and net-exchange



radiometers, portable heat-flow meters, and soil heat-flow recorders. **Beckman & Whitely, Inc., 915 San Carlos Ave., San Carlos, Calif.**—TELE-TECH & ELECTRONIC INDUSTRIES.

CIRCUIT BREAKERS

E-T-A thermal, single-pole, miniature over-current circuit breaker has been designed to protect ac motors, TV sets, instruments, and other kinds of electrical and electronic equipment. The bimetal thermal overload device is amply rated, and cannot be tampered with. Maximum voltage ratings: 250 v. ac, 24 v. dc. Current ratings: from 50 ma up to 25 amp. The breaker can be



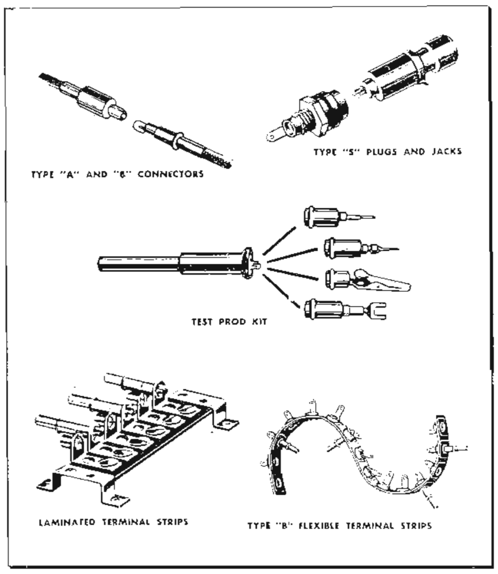
used for 230 v. dc if the prospective short circuit current does not exceed 6 amps. Overall length, 2.44 in., width, 1.221 in., depth, 0.571 in. Weight, approx. ½ oz. **E-T-A Products Co., 915 W. Oakdale Ave., Chicago 14, Ill.**—TELE-TECH & ELECTRONIC INDUSTRIES.

More product reviews can be found on pages 116 and 118.

INDUSTRIES

CONNECTORS

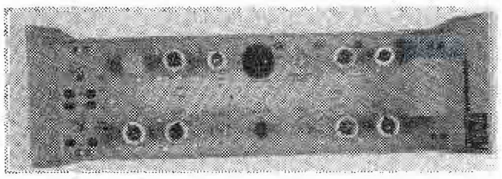
"Interlock" electrical connectors incorporate an automatic locking connection that cannot be accidentally



disconnected. The plug engages automatically, but can be easily and quickly disconnected. When locked, the vibration-proof connection has a constant low resistance and makes two separate contacts that are under constant spring pressure. Decrease in one contact surface automatically increases pressure on the other. Various types of "Interlock" connectors include: metal and insulated automatic locking plugs and jacks, right angle plugs, connectors, splicing links, and flexible aluminum terminal strips that can be cut to length and bent or curved to any form fitting wiring design. Also included is a 4-in-1 test prod with interchangeable attachments that lock automatically to the prod coupler. **Harvey Hubbell, Inc., State & Boswick Ave., Bridgeport, Conn.**—TELE-TECH & ELECTRONIC INDUSTRIES

REMOTE SYNC HOLD

The FTL-87A remote sync hold is designed to bring a studio synchronizing generator into exact synchronization with the sync component of a



remote video signal. Accomplished on a gradual basis, a local program brought in will not roll on home receivers while the sync generator is being locked to the remote sync. Once local-remote synchronization is established, montages, superimpositions, and other special effects can be produced using both local and remote or network video signals simultaneously through use of such additional units as FTL-93B scanner. **Federal Telecommunication Laboratories, 500 Washington Pl., Nutley, N. J.**—TELE-TECH & ELECTRONIC INDUSTRIES.

MAGNETS

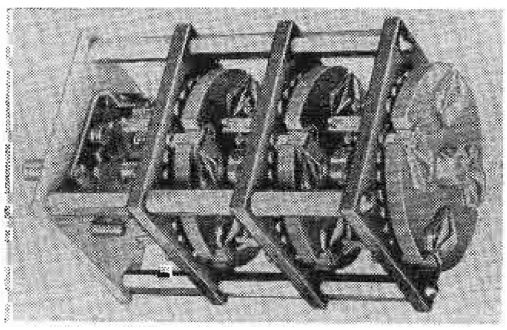
"Magnadur," said to be the first ceramic permanent magnet material to be made in the U.S., contains no nickel, cobalt, tungsten, or other critical material. The product is a very hard, brittle, black pottery-like substance made from a mixture of barium and iron oxide by a powder metallurgy process. The mixture is pressed or extruded to shape, then sintered at high temperatures. Its high coercive force, high demagnetization resistance, and magnetic stability enables the use of Magnadur magnets in the presence of hf fields without magnetic loss. For the remainder of 1953, the initial production of the new material will be concentrated on toroidal rings developed for TV focusing ring magnets. The double lens system, using two Magnadur rings, reduces stray fields to a minimum and provides undistorted pictures with uniform sharpness. **Ferroxcube Corp. of America, 233 Marshall St., North Adams, Mass.**—TELE-TECH & ELECTRONIC INDUSTRIES.

RESISTORS

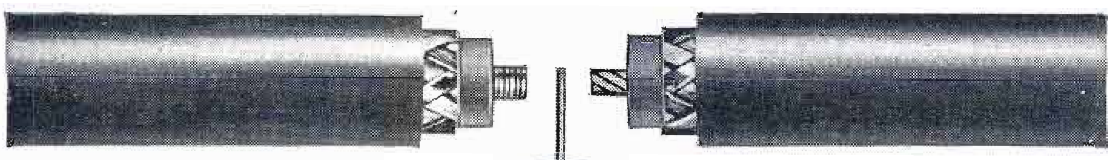
Standard Stackpole ½ watt, fixed-composition resistors are now available with formed and trimmed leads which facilitate resistor handling when components are assembled on the standard 0.062 in. printed wiring base. The hot tin-dipped leads are cut and formed for a tight "spring fit" and extend through the circuit base just far enough to enable easy soldering. Resistors snap into place. No other operation is needed for assembly. **Electronic Components Div. Stackpole Carbon Co., Tannery St., St. Marys, Pa.** —TELE-TECH & ELECTRONIC INDUSTRIES.

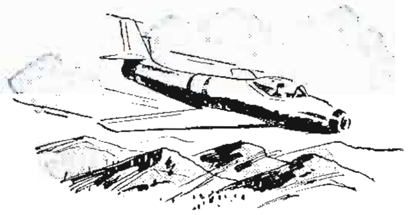
SWITCHES

All switches now made by the Daven Co. are constructed in accordance with JAN and MIL specifications. Further, they incorporate silver-alloy contacts and slip-rings, knee-action rotors, and positive roller-type detent actions. Switch stops are independent of the rotors. A principal advantage of the present design is that a large number of positions and poles can be contained in a very small space. Also, it enables

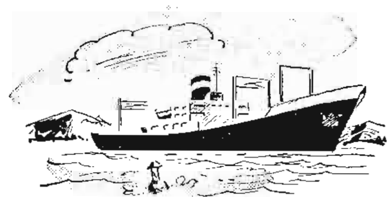


the presentation of a broader selection of positions and poles. **The Daven Co., 191 Central Ave., Newark 4, N. J.** —TELE-TECH & ELECTRONIC INDUSTRIES.

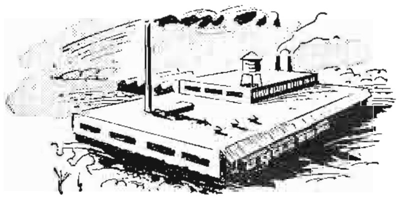




AVIATION



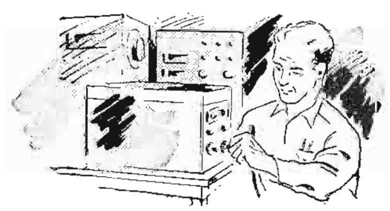
MARINE



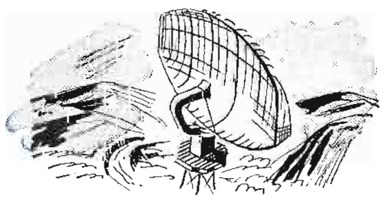
INDUSTRIAL

BROADCASTING

RADIO-TV LEAD-INS



TEST EQUIPMENT



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Federal offers you one of the nation's most diverse stocks of RG type cables—including the Federal-developed low-temperature, non-contaminating thermoplastic jacket.

Quality-controlled throughout the entire manufacturing process, Federal cables bring *trustworthy transmission* to every electronic application . . . *plus* top flexibility and superior resistance to abrasion, weathering and corrosion.

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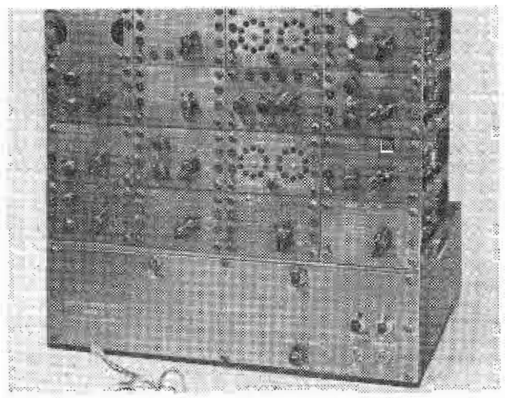

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Transistor Transient

(*Continued from page* 69)

ever, this basic equivalent circuit fails completely at higher frequencies and in the prediction of transient response. It is desirable, at this point, to investigate more fully the transport factor, β, and to determine how it contributes to the frequency and transient response of the transistor circuit.

Diffusion Process

Semiconductor physics has shown that holes and electrons in semiconductors may move under the influence of either, or both, (a) an electric field gradient or (b) a concentration (density) gradient.[1] It has further been shown that, except in close proximity to the barriers, minority carriers in a p or n region are influenced predominantly by a concentration, rather than an electric field, gradient. In the ensuing analysis, this assumption will be considered valid, and the electric field effects on carrier motion will be neglected entirely. However, it should be remembered that this assumption is never absolutely valid, and in particular, in such transistor devices as tetrodes or transtrictors (unipolar devices), the electric field is of prime importance.

When particles of any sort move as the result of a density gradient, the resultant motion is described as diffusion. Carrier diffusion in the base region of a transistor is characterized by the fact that the density of carriers may be modulated at the emitter junction but is almost zero at the collector junction. A physical analogy of the diffusion of carriers through the base of a transistor may be made to thermal diffusion in a metal rod.[5]

The diffusion mechanism in transistors can be calculated mathematically by application of two fundamental physical laws: the continuity-of-flow equation and the current-gradient equation. It can be shown that the diffusion equation for transistors is: [1,2,4] (1), (2), (4):

$$\frac{\partial m}{\partial t} = D_m \nabla^2 m - \frac{m - m_e}{T_m} \quad (3)$$

where m is the carrier concentration density, m_e is the thermal equilibrium concentration of carriers in the base, T_m is the mean carrier lifetime and D_m is a diffusion constant. For most modern junction transistors, the width of the base region (W in Fig. 1) is very small compared to the length of the base (B in Fig. 1), and so Eq. 3 may be simplified to a one-dimensional representation, which assumes

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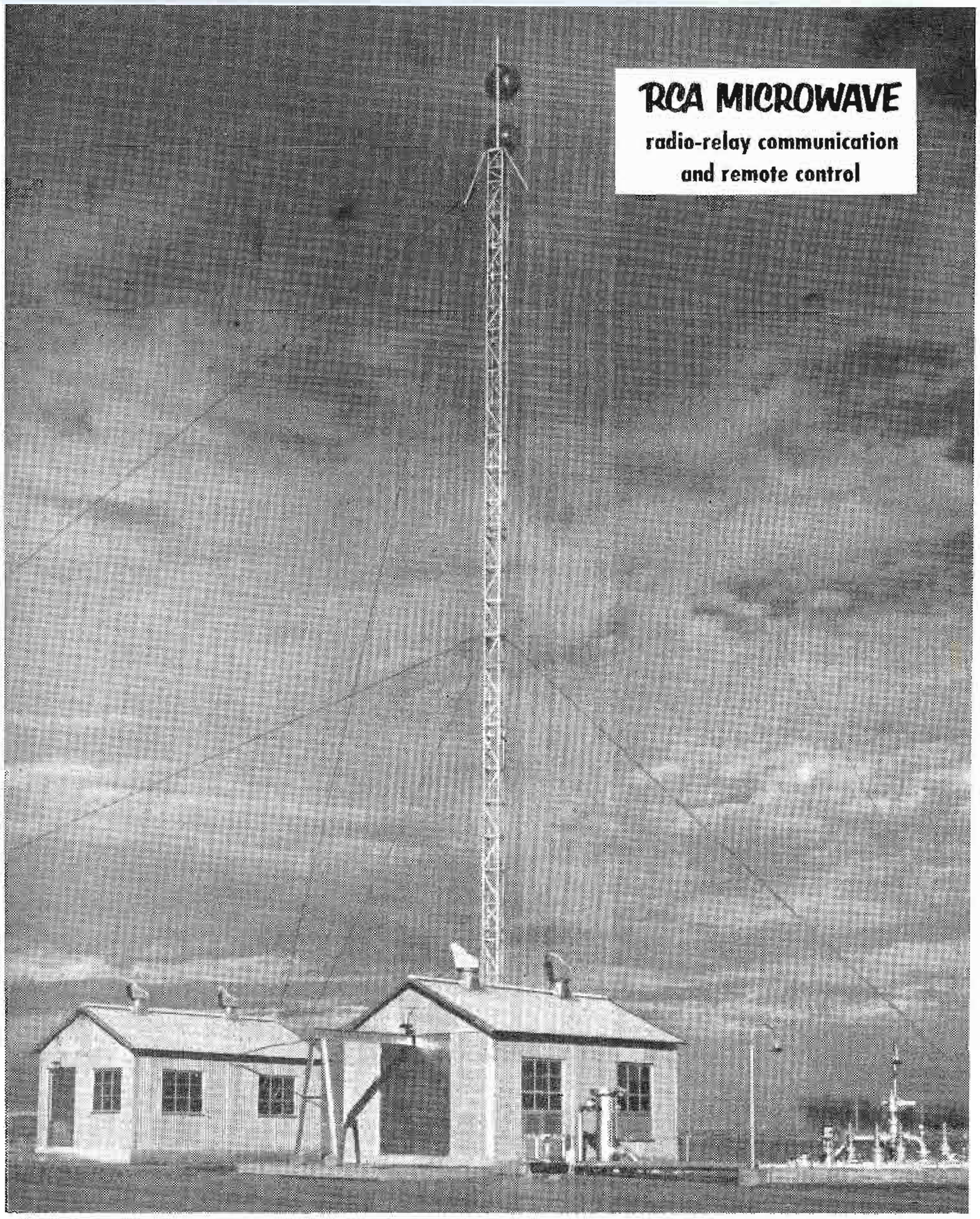
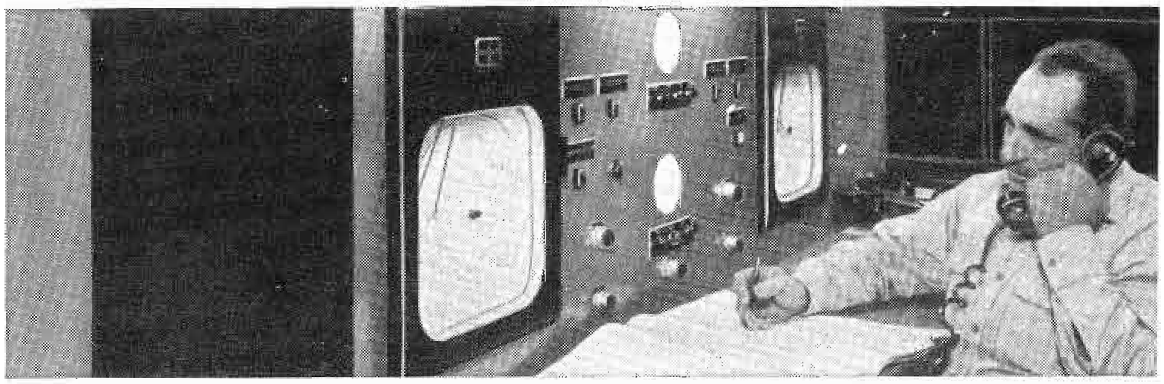


Unattended booster station at Pernell, Okla. Radio-beam signals via RCA Microwave operate the booster by full remote control. Maintenance man inspects each station once every 24 hours.



Telemeter charts give continuous record of power and pressures at boosters. Operator remote-controls valves and pumps of booster stations. Signal lights indicate equipment failure and emergency generator operation. 2-way voice channel contacts maintenance personnel.

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TRANSISTOR TRANSIENT (Cont.)

that carrier flow into the base lead of the transistor may be neglected. If the one-dimensional diffusion equation is solved for the current transfer ratio across the base region, assuming an injection ratio of unity, i.e., i_c/i_e for $\gamma=1$, the current amplification factor, α, is found to be:

$$\alpha = \frac{i_c}{i_e} = \text{sech}\left\{\frac{W}{\sqrt{D_m T_m}}\sqrt{1+j\omega T_m}\right\} \tag{4}$$

where W is the width of the base. Eq. 4 indicates the variation of α with frequency which results from a simple diffusion process, and is limited in usefulness by the many simplifying assumptions which were made in its derivation. Nevertheless, from Eq. 4 it is possible to learn how the equivalent circuit of Fig. 4 must be modified for the diffusion process to be taken into account.

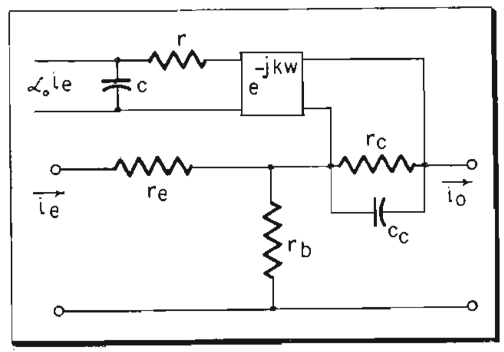


Fig. 7: Transient small-signal equivalent

A transmission line, such as is illustrated in Fig. 5, has a short-circuit current transfer ratio given by[6]

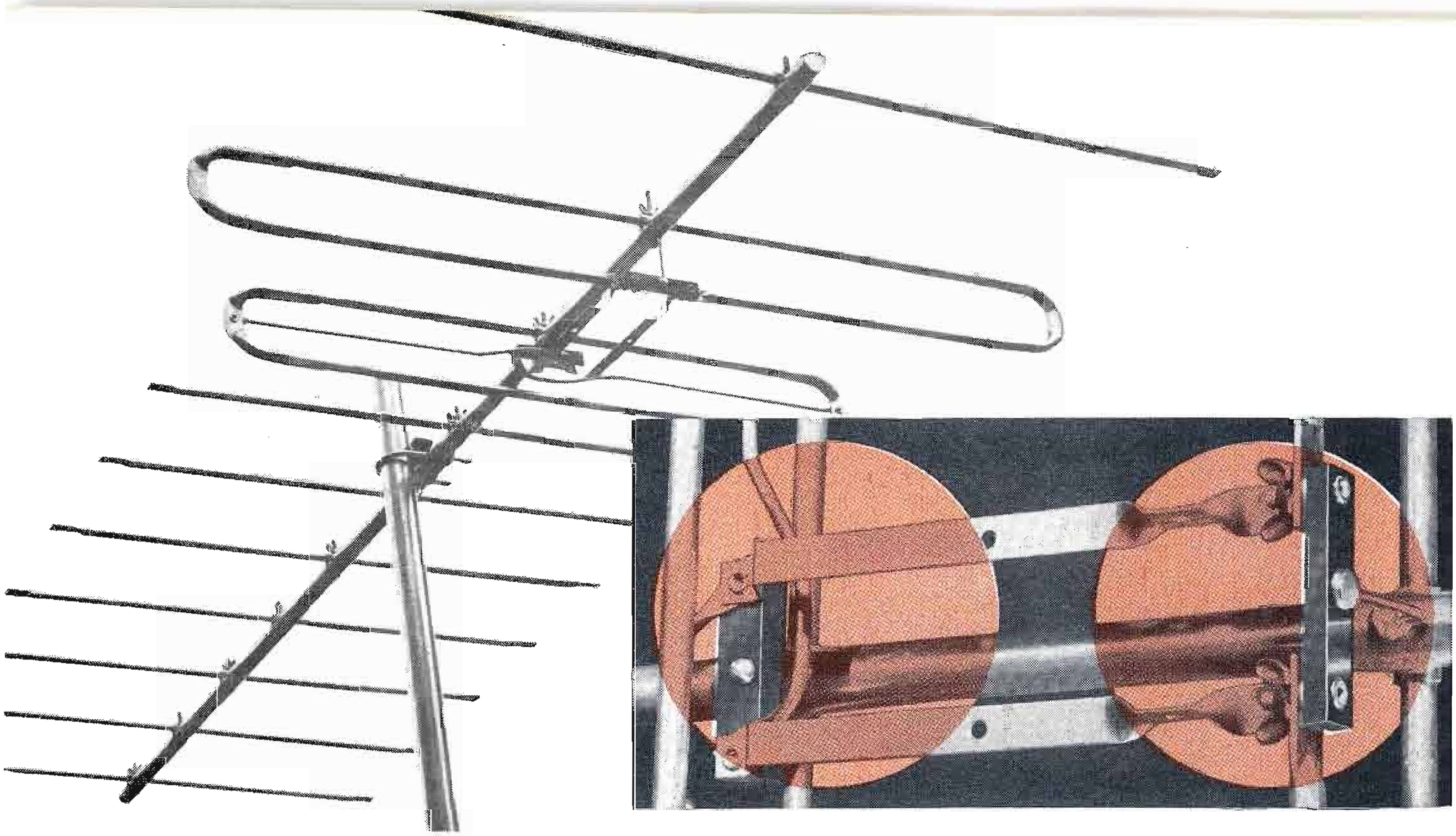
$$\frac{i_o}{i_i}(j\omega) = \text{sech}\sqrt{YZ} = \text{sech}\sqrt{\frac{r}{r_s}+Cr_s j\omega} \tag{5}$$

Eqs. 4 and 5 are mathematically identical. Thus, the transmission line of Fig. 5 may be used as an electrical analogy to the diffusion process in the base of a transistor. The circuit of Fig. 4 can be modified accordingly.[7]

Modified Transistor Equivalent Circuit

In order to account explicitly for diffusion, injection ratio, collector current multiplication and base-width modulation, an equivalent circuit is required which is much more complicated than any yet published. Such an equivalent circuit, for example, is illustrated in Fig. 6.

Z_λ is a complex impedance which represents the injection-ratio effect. μv_c is a voltage generator, which must be included in the equivalent circuit to account for the effect of barrier modulation[3] (by the collector



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TRANSISTOR TRANSIENT (Cont.)

voltage, v_c), on the input side of the transistor. Both r_c and C_c are functions of v_c because of barrier modulation. The transmission line between the current generator, i_e, and the collector represents the diffusion effect, whereas the complex current source, $\alpha^*(v_c)\, i_e$, accounts for collector current multiplication effects. Despite the apparent complexity of this circuit, it is still limited to analysis which neglects the variation of r_e, r_b and r_c with dc currents. Thus, the equivalent circuit of Fig. 6 is valid only for linear ac analysis.

Transistor Behavior

The complexity of tying in the known physics of a transistor with a suitable equivalent circuit should now be apparent. In general, however, it is possible to approximate the transistor behavior by simplified equivalents. For example, the circuit of Fig. 4 may be used to represent a transistor at low frequencies and for small signals. The authors have shown[7] that the circuit of Fig. 7 may be used for transient analysis where the following assumptions are made:

(a) $\gamma = 1.0$

(b) $\alpha^* = 1.0$

(c) variation in collector voltage negligible ($\mu v_c \cong 0$)

(d) one-dimensional diffusion

Condition c implies that the circuit is valid only for small signals. The circuit of Fig. 7 approximates the delay and dispersion properties of diffusion (the analogy of which is the transmission line shown in Fig. 6) by the ideal delay line and a simple r-c integrating network. Using devices of this sort, it is possible to make relatively simple approximations to the transient and frequency response characteristics of transistor networks.[7] Naturally, how close the approximation comes to the physical case depends upon how close the transistor model, together with its implied assumptions, approximates the physical device.

Calculation of the transient response of transistor circuits requires some understanding of the fundamental physics of semiconductors. A suitable equivalent circuit for the transistor, which takes into account all of the known physical principles significant to transistor operation, is not yet available to the circuit engineer. An exact equivalent circuit would have to represent such phenomena as:

(1) base-width modulation by collector voltage[3]

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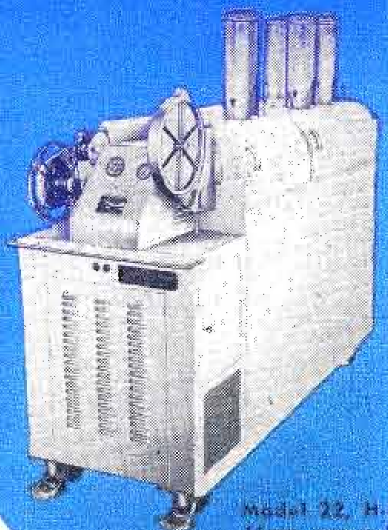

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TRANSISTOR TRANSIENT (Cont.)

(2) carrier diffusion effects in base[1,4,5]
(3) injection ratio[3]
(4) collector current multiplication[4]
(5) variation of r_e, r_c with current

Specific Use

It is generally possible to neglect one or more of these considerations in reference to a specific circuit application of the transistor. However, it must be remembered that any one of the simplified equivalent circuits currently in use is limited to a specific use by the assumptions which were made in deriving it. A transistor which deviates from the assumed equivalent circuit in performance is not necessarily a bad transistor. In general, the equivalent circuit itself must be modified considerably if more transistors are expected to follow circuit theory.

Acknowledgement. This work has been supported by the USAF Air Research and Development Command, USAF Air Materiel Command, Army Signal Corps and Navy Bureau of Ships under contract AF33(600)-17793.

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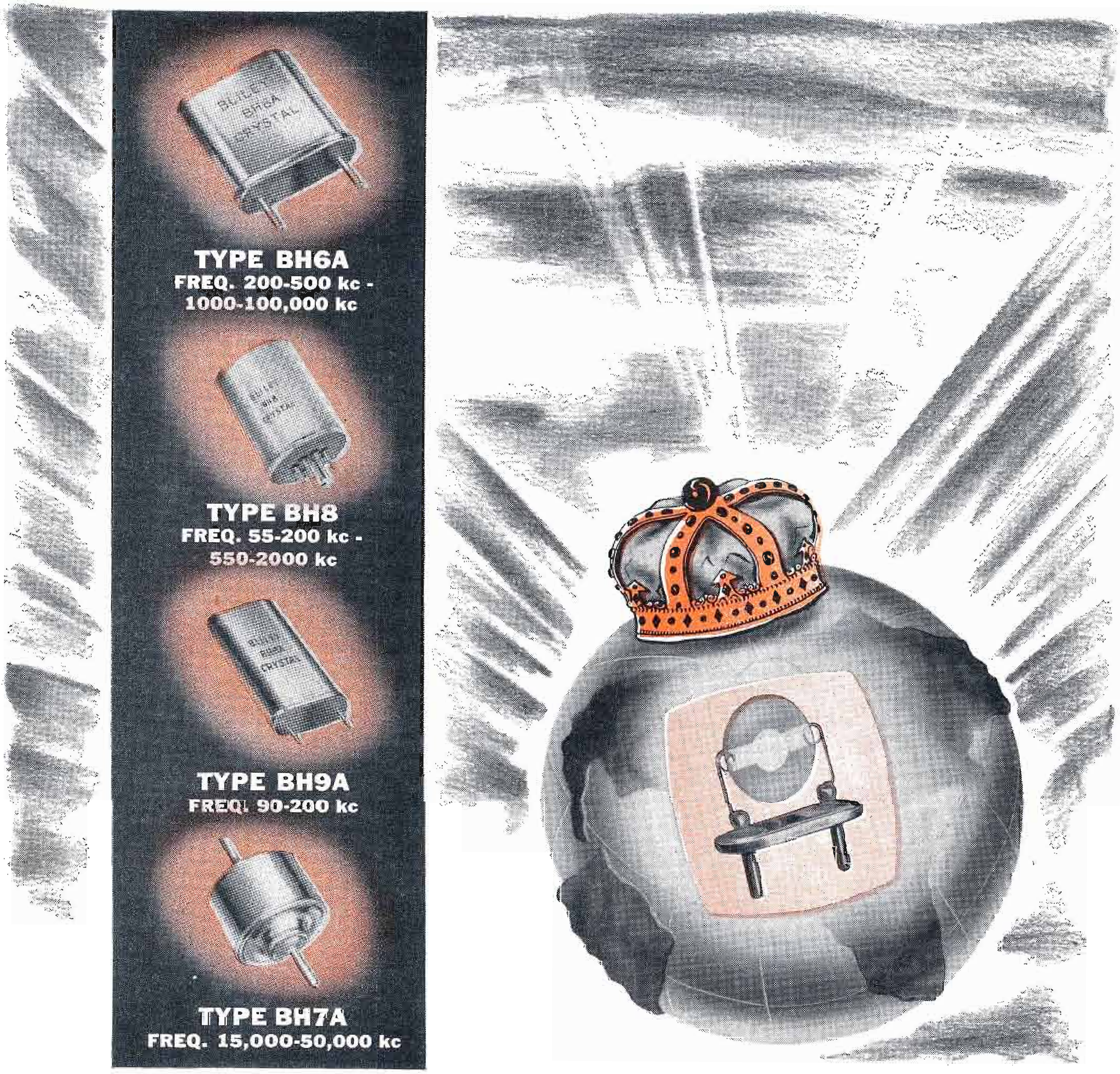

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(Continued from page 89)

two transformers will be required; for a higher degree transfer function it is clear that use of this method will require a larger number of transformers. It is of course desirable that only one real transformer be used, and we now demonstrate an alternate procedure that requires only one real transformer.

In the net work of Fig. 6 we may remove the poles with the smaller

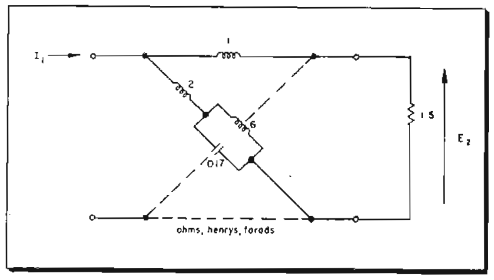

Fig. 10: Lattice achieved for example

residues as was done previously. This is optional with the designer. However, we must always leave a part of the inductance branch in the cross arm and remove a part of it as a shunt branch across the input and output terminal pairs. Thus if $y_{1b} > y_{1a}$, we may remove y_{1a} from each arm; however, for $y_{1a} > y_{1b}$, as we have assumed in this illustration, we remove only a part of y_{1b} from each arm. (We can, of course, for this case initially perform a rotation of the output terminals so that the resulting cross arm will have a larger residue in the pole at the origin). It will become clear that the amount we remove in any particular example depends on the coupling coefficient we wish to achieve. Suppose we remove $y_{1b}/2$ from each arm. Now we separate the lattice into only two paralleled four-terminal networks, as shown in Fig. 8. Since the admittance of the arm

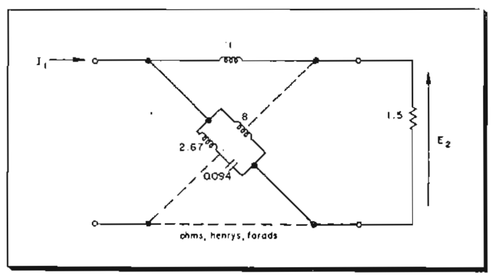

Fig. 11: Lattice equivalent to that in Fig. 10

of the lower network contains a zero at infinity, we can obtain a series inductance by expanding the impedance of this arm as a Foster network. This series inductance can then be used as the leakage inductance of the real transformer. The form of network obtained is shown in Fig. 9 (a), while Fig. 9 (b) shows the ideal transformer replaced by a real transformer.

It is thus clear that we can always obtain an unbalanced form of network that employs at most one real transformer and no ideal transformers.

We are given

$$Z_{12} = \frac{E_2}{I_1} = \frac{s^3 + 7s}{s^3 + s^2 + 3s + 1} = \frac{p}{q}$$

which we wish to realize within a multiplicative constant H as a lossless unbalanced network terminated in resistance and containing at most one real transformer.

We work with

$$K' = E_2/E_1 = \frac{p}{Hq}.$$

Dividing the numerator and denominator by the even part of the denominator yields

$$K' = \frac{(s^3 + 7s)/(s^2 + 1)}{H\,[1 + (s^3 + 3s)/(s^2 + 1)]}.$$

We compute the residues and the values of H.

Pole at infinity:

$$k_1^{(n)} = 1$$
$$k_1^{(d)} = 1$$
$$\therefore H = k_1^{(n)}/k_1^{(d)}\ a = 1.$$

Pole at $s = \pm j1$:

$$k_3^{(n)} = 3$$
$$k_3^{(d)} = 1$$
$$\therefore H = k_3^{(n)}/k_3^{(d)} = 3.$$

Suppose we are interested in sav-

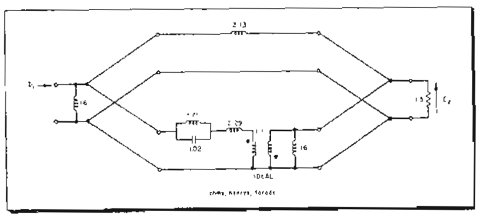

Fig. 12: Intermediate unbalanced network

ing elements. Therefore we choose H equal to 3. Then

$k_1^{(a)} = 1 \qquad k_3^{(a)} = 0$

$k_1^{(b)} = 2 \qquad k_3^{(b)} = 3$

and the load resistance R for the Z_{12} is $R = H/2 = 1.5$ ohms. The lattice arms are

$$Z_a = s$$

$$Z_b = 2s + \frac{6s}{s^2 + 1} = \frac{2s\,(s^2 + 4)}{s^2 + 1}$$

and the lattice shown in Fig. 10 realizes

$$Z_{12} = (1/2)\ p/q.$$

We now proceed to convert the lattice to an unbalanced form. We find

$$Y_a = \frac{1}{s}$$

$$Y_b = \frac{1/8}{s} + \frac{3s/8}{s^2 + 4}$$

which yields the equivalent lattice shown in Fig. 11.

We first remove an inductance with an admittance value of 1/(16s)

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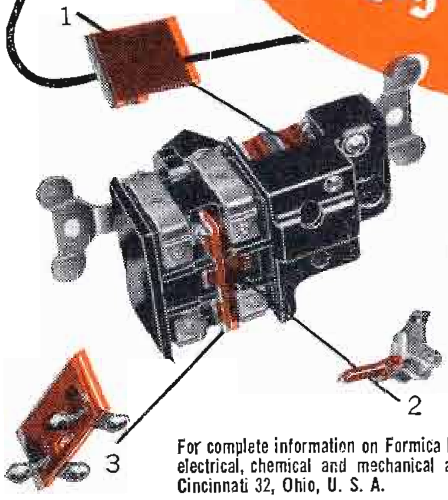

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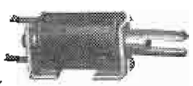

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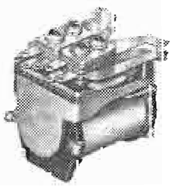

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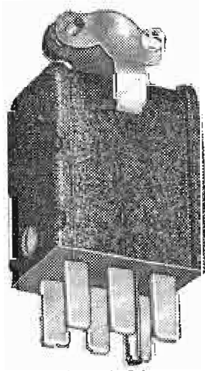

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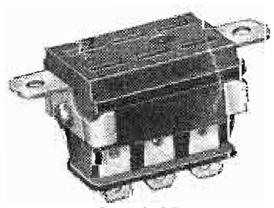

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from each arm and then divide the lattice into two parallel networks. The $[Y_b - 1/(16s)]$ is now realized by a partial fraction expansion of its impedance:

$$Z = 1/[Y_b - 1/(16s)]$$
$$= \frac{16s\,(s^2 + 4)}{(s^2 + 4/7)}$$
$$= \frac{16s}{7} + \frac{48s}{49\,(s^2 + 4/7)}$$

The network achieved thus far is shown in Fig. 12.

We can now replace the ideal transformer by a pair of coupled coils with a non-unity coupling coefficient. The final network is shown in Fig. 13.

In order that a transfer function be physically realizable by a lossless coupling network terminated in a single resistance, it must have an odd or even numerator. In this paper a method has been demonstrated for realizing any of these transfer functions by means of a lossless lattice network terminated in resistance. With the further restriction of an odd numerator for a transfer impedance and an even numerator for a transfer admittance or transfer voltage ratio, the achieved lattice can always be reduced to an unbalanced network with the use at most of one real transformer, where the real transformer is defined as one that has finite magnetizing inductance and a coupling coefficient smaller than one. Such a network finds many practical applications in circuit design.

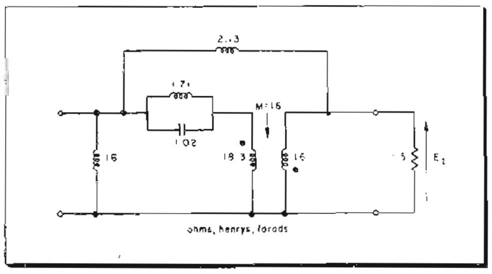


Fig. 13: Final network realizing given transfer function with use of no ideal transformers

The research described herein was under the supervision of Dr. E. A. Guillemin, and was supported in part by the Air Materiel Command, the Army Signal Corps, and the Office of Naval Research.

1. L. Weinberg, "The Darlington Problem," *J. Apply. Phys.*, June, 1953.
2. E. A. Guillemin, "A Summary of Modern Methods of Network Synthesis," *Advances in Electronics*, vol. III, Academic Press, Inc., New York, 1951.
3. L. Weinberg, "A General RLC Synthesis Procedure," paper presented at the March 1953 I.R.E. Convention.
4. J. L. Bower and P. F. Ordung, "The Synthesis of Resistor-Capacitor Networks," *Proc. I.R.E.*, March 1950.
5. E. A. Guillemin: *The Mathematics of Circuit Analysis*, John Wiley and Sons, Inc., New York, 1949.
6. L. Weinberg, "New Synthesis Procedures for Realizing Transfer Functions of RLC and RC Networks," Technical Report No. 201, R.L.E., M.I.T., Sept. 1951.
7. E. E. Department, M.I.T.: *Magnetic Circuits and Transformers*, John Wiley and Sons, Inc., New York, 1943.

Project "Tinkertoy"

(*Continued from page 72*)

desired. Such changes would not en-
desired. Such changes would not en-
tail the re-training of hundreds of assemblers along a belt, nor under many conditions would it be necessary to bring in many new components.

2. Freedom from dependence on outside suppliers for the bulk of the components because these are processed in the factory from raw materials.

3. A very high production rate as far as the number of workers are concerned and these do not have to be especially skilled.

4. Electronic products are turned out that are of high quality and great uniformity. This is assured by 100% inspection.

5. The automatic machinery is not unduly complicated nor unreliable. In general the machines are simpler than many used in tube production.

Possible Disadvantages

The disadvantages that follow, real or fancied, are some mentioned by engineers viewing Project Tinkertoy in operation. They are mentioned to stimulate thought, not

Fig. 8: R. L. Henry of NBS examines pattern printer for printing six wafers simultaneously

to detract in any manner from this forward-looking, excellently-carried out project of the National Bureau of Standards.

From the designers view point:

1. Circuits having elements other than R and C are more difficult to adapt and automatically assemble at the present time.

2. No shielding, either static or magnetic, within a unit.

3. Arrangement of riser wires do not permit leads of minimum length, so necessary for some high frequency radio circuits.

4. Not all sizes of vacuum tube sockets, or other bulky components,

PROJECT TINKERTOY

Released By The Government And Now Available To Industry

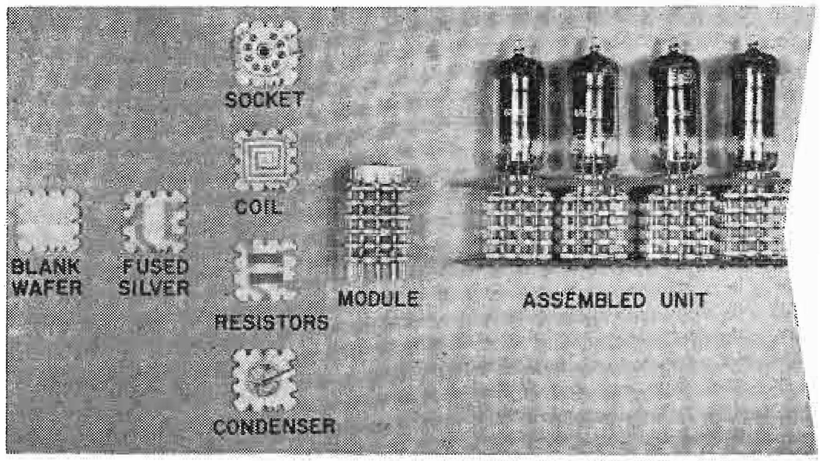
what it is

Project TINKERTOY is the code name for a development by the National Bureau of Standards. It consists of a design system and automatic machinery for the MECHANIZED PRODUCTION OF ELECTRONIC EQUIPMENT. This program was sponsored by the Navy Bureau of Aeronautics as an industrial preparedness measure in production research.

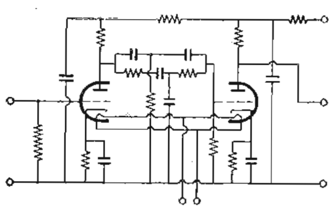
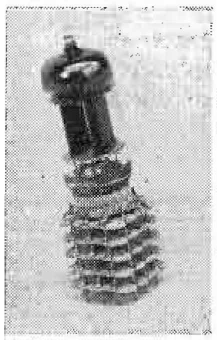
how it affects your production of electronic equipment

A high speed mechanized production process, the Project TINKERTOY method is also economical for small quantities.* Production of one *or* one million units is practical without design change. The ultimate in standardization of tooling and assembly is possible, and a minimum of skilled labor is required. Under this new design system you easily shift production over a wide range of products — rapidly and economically. This new mechanized production method guarantees uniformity of product *plus* automatic quality control, giving increased reliability. Production engineering costs are minimized because the development model actually *is* the final production design.

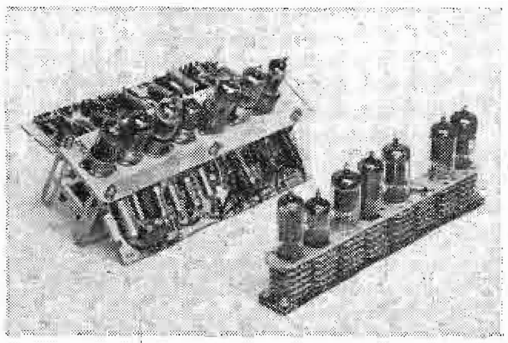
* Small pilot runs, using an equivalent hand module assembly method, are actually competitive with quantity production runs by present day methods.



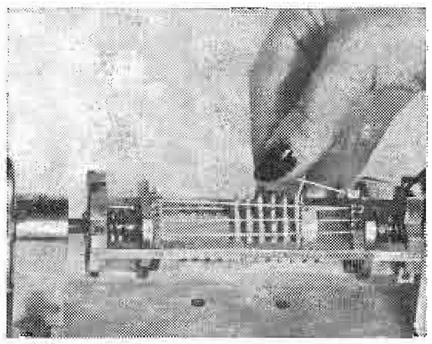
The heart of the N.B.S. system is the "module", consisting of half a dozen ceramic wafers interconnected by a dozen "riser" wires. Each wafer can contain as many as four tape resistors, ceramic disk condensers, or a tube socket, plus silvered connections to the proper riser wire. A single module can contain an entire circuit including a tube socket and twenty components as illustrated below left. Coils and other miscellaneous components can also be included. Several modules can be sandwiched between two photo-etched circuits providing a complete package. Audio, video, IF and RF amplifiers; oscillators, sweep circuits and counters have been made by this method. Tests by Sanders Associates have shown this equipment capable of withstanding environmental conditions beyond Military requirements.

 = 

This entire circuit can be contained in one module



Section of radio altimeter before and after adaptation to Project TINKERTOY by Sanders Associates



Hand module assembly jig

Sanders Associates is proud to have been a member of the team contributing to this revolutionary development of the National Bureau of Standards and sponsored by the Navy Bureau of Aeronautics. Our responsibility was the developing and establishing of hand assembly facilities for pilot-line production. Sanders Associates successfully applied the Project TINKERTOY principles to a submarine detecting device, a radio altimeter and other military equipments.

Now Sanders Associates is able to offer to the industry its "know-how" obtained during two years of redesign engineering in association with Project TINKERTOY. We are ready to assist in engineering the conversion of conventional electronic equipment to the modular design technique, leading to automatic production. Why not send for our recent bulletin on Project TINKERTOY? Address inquiries to Department 61.

SANDERS ASSOCIATES INCORPORATED

NASHUA, NEW HAMPSHIRE

reliability in electronics

could be mounted on the standard wafer.

From the manufacturing viewpoint:

1. In the pilot plant the production line was not continuous. The output

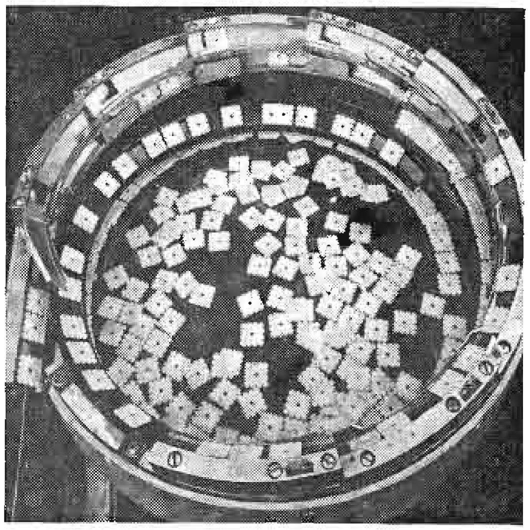


Fig. 9: Vibratory bowl feeder issues oriented wafers to machines. Spiral channels have stops to check position of wafer keying notch

of various machines was collected in metal containers and then *carried* to the next machine. At present the line does not extend far enough, that is, to the finished, packaged product.

2. Unless the output of an automatic machine is promptly and frequently inspected by a robot tester it is possible with high-speed production, when a defect in the process creeps in, to pile up thousands of rejects before the fault is noticed.

3. Unless duplicate facilities are provided, or a reservoir of parts

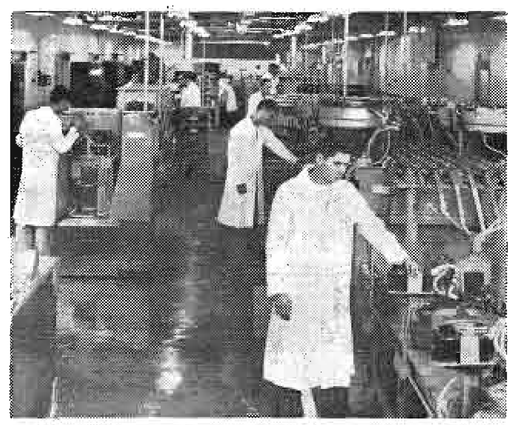


Fig. 10: Interior of Tinkertoy pilot plant

mounted on wafers is available, production would be seriously interrupted (as in manual assembly) and machines made idle by the failure of any link in the automatic process.

4. The structure of the unit, or "module," is such that repair of defective units in the factory would be difficult and in the field practically

"Color Television"

A special issue containing

• 15 N.T.S.C. Monographs—

The National Television Systems Committee has authorized IRE to publish its long awaited Monographs in the January 1954 special Color Television issue of "Proceedings of the I·R·E" — thus giving them industry-wide distribution for the first time in print.

• 25 additional Color TV articles—

will also appear in this issue, which brings the reader up-to-the-minute on the developments of Color Television. Copies of the first Color Television issue are still available and combined with this second Color Television issue will form a complete bibliography of major historical importance. Also included in the January issue will be a complete listing of the N.T.S.C. system specifications as submitted to the F.C.C.; and field test reports on the system's performance.

in "Proceedings of the I·R·E" January '54

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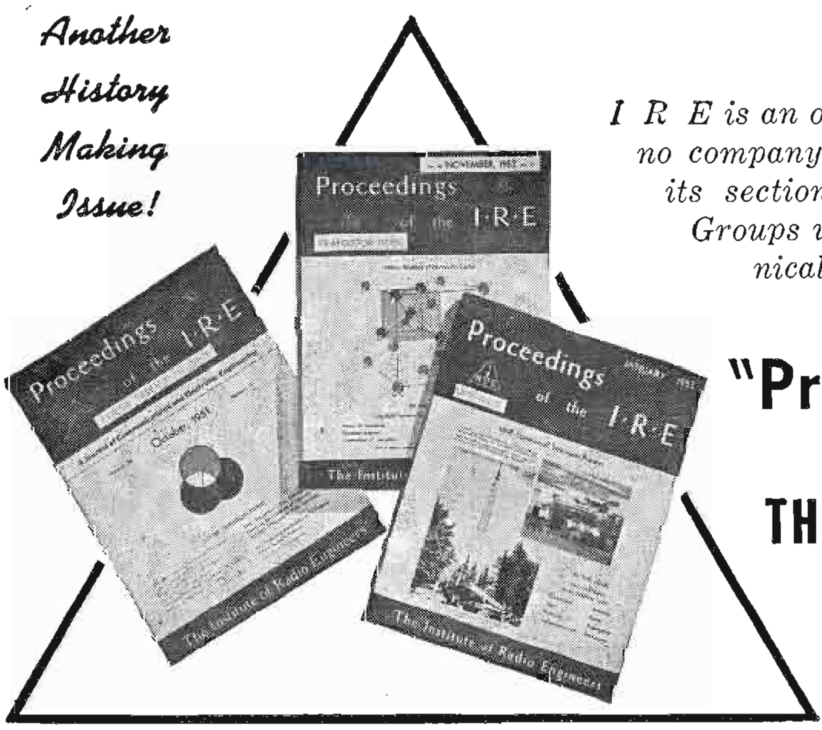
Another History Making Issue!



I R E is an organization of 33,312 member-engineers. There are no company memberships. Operating continuously since 1913, its sections meet in 78 cities. 21 specialized Professional Groups widen the scope of its member-services and 40 technical committees help the industry.

"Proceedings of the I•R•E"

Published by

THE INSTITUTE OF RADIO ENGINEERS

1 East 79th Street, New York 21, N. Y.

Please place orders before December 10th.

PROJECT "TINKERTOY" (Continued)

impossible, therefore one would throw away the defective unit, replacing it with a new unit. The interchangeability and low cost of the units makes this feasible. Actually this may be the trend of maintenance in the future.

All patents in connection with Project Tinkertoy will be made public property. The Navy pointed out that they have backed this project to the point where a practical, usable product is being turned out. They want industry to take up the idea and extend the field of automatic fabrication.

WABT On Air

Station WABT (formerly WAFM-TV), Birmingham, Ala., is now on the air with what is reported as the world's first 50 KW TV transmitter. Operating on Channel 13, the station is now broadcasting with an effective radiated power of 316 KW. Standard Electronics Corp. of Newark, N. J., provided the equipment.

SHAPE Invites Broadcasters

Brig. Gen. William P. Nuckols, Chief of Public Information, Supreme Headquarters Allied Powers Europe, has extended an invitation to NARTB members who will be in Europe this fall, to visit SHAPE facilities in Paris. Advance plans can be made through Public Information Div., SHAPE, APO 55, c/o Postmaster, New York. In Paris, call Galvani 3000.

NEW SMPTE OFFICERS

Newly elected officers of the Society of Motion Picture and Television Engineers are (left to right) the new financial vice president, Barton Kreuzer, manager of theatre and industrial equipment, RCA Victor Div.; engineering vice president, Axel G. Jensen, director of television research of Bell Telephone Labs.; and treasurer, George W. Colburn, George W. Colburn Laboratory, Inc.

GE Anniversary

(*Continued from page* 102)

a particular product is arrived at, and how a product flows through a manufacturing plant. Fig. 4 summarizes this operation at G. E.'s Radio and TV Department at Electronics Park.

The product planning group of the marketing section has the responsibility of studying carefully every aspect of the new product, coordinating the efforts of all other functional areas of the department.

In charting the course of the television receiver beyond this product planning group, only the actual TV model is followed. A more comprehensive diagram would show similar flow lines for operational plans, specifications and schedules.

An attempt has been made to show the points at which research and development, drafting, components engineering, manufacturing, cost accounting and purchasing apply. However, it should be understood that any or all of these important functions might be called back into play anywhere along the line from management to final product for consultation or for solving problems which inevitably arise in developing any new product.

Congratulations are due all in the General Electric Co. on this wonderful occasion, and especially to those individuals with the Electronics Division. The outlook for the future is brighter than ever for now the electronic industries are coming into their own. Some might say that because theoretical electronic boundaries have now been more or less established, and because components and equipment are becoming more and more standardized and hence

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9. Absence allowances for illness and personal business.
10. Discount on purchase of G-E products.

GE Anniversary (Continued)

more reliable, that the industry limits are in sight.

But from the application viewpoint it is obvious that this is not true and that the surface has barely been scratched. Color television, video recording and automation are but a few of the many areas destined to see great advances in the next twenty-five years.

Diode-Capacitor

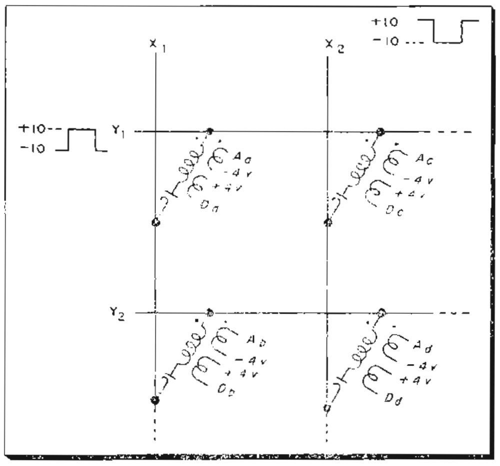
(*Continued from page* 85)

normal voltages of −4 and +4 volts. Then the capacitor is left with a charge of 2 volts and upon the next squeeze will produce a positive pulse at E, i.e., a "one" has been written. The opposite is equally possible: forcing E negative until the end of the squeeze will write a "zero." Once the diodes have been returned to their normal voltages, the charge on the capacitor will be undisturbed by later changes at E, provided that the magnitude of the voltage at E never exceeds 2 volts. Thus E can have other pulses on it, either positive or negative, and the charge stored on the capacitor will remain unaffected because both diodes will remain with backward bias. This is important for organizing many basic storage elements into an efficient memory assembly and is the reason for charging the capacitor to only ±2 volts while biasing the diodes twice as much.

In this description the diodes have been assumed to be ideal, having practically infinite forward conductance and practically zero backward conductance. The effect of finite forward conductance will reduce somewhat the output pulse amplitude, and it will determine how long a writing pulse must last to charge the capacitor adequately. The effect of finite backward resistance, however, is critical. During the holding operation relatively long times will elapse, and even minute currents through the diodes would disturb the capacitor charge. The unit would gradually leak toward a condition of no charge on the capacitor or even a condition on which the sign of the charge on the capacitor is reversed. Thus the permissible duration of the holding operation is determined by the rate at which the capacitor leaks charge through the diodes' back currents. Arbitrarily long periods of storage of information are achieved by regneration; before the capacitor charge can change to a point where there is danger of losing the information, the memory control circuits read the content of each cell and rewrite it.

An amplifier is accordingly needed at point E to sense the polarity of E during the early part of the squeeze period, together with a gate structure which will force E to the desired polarity during the latter part of the squeeze period. For reading or regeneration, E is forced to the same polarity that was read; for writing new information the polarity to which E is forced is independent of what was read, but is determined by the new information being written. Such a gating amplifier is easy to construct. The amplification required is small since the input is a pulse whose amplitude is of the order of one or two volts. The gating can be accomplished with standard techniques, and the circuit can be constructed using 2 or 3 vacuum tubes and about a dozen diodes.

In order to achieve acceptable efficiency, it is essential that the gating amplifier serve many basic stor-



Portion of word selection matrix for providing rapid access to information stored in memory

age elements. The busses to the diodes are made common to all the digits of a particular computer word, and a particular gating amplifier serves the same digit on each of many words. Thus for 256 words of 50 binary digits each there would be 256 pairs of leads to the diodes and 50 gating amplifiers. For reference to a particular word, the proper pair of busses are squeezed to zero voltage, while all the other pairs are held at their normal value of -4 and $+4$ volts. In this way each gating amplifier receives a pulse from its particular digit of the selected word so that the word is available in parallel at the gating amplifiers. They can then write into this word or rewrite it without affecting the other words in the memory since all diodes in other words remain with backward bias. After the squeezing busses on this word are returned to normal, any other word may be referred to in the same way. This is

NBS DEVELOPMENTS (Continued)

the basis of a fully parallel, random-access memory. Regeneration is handled by having the memory control intersperse regeneration cycles, in which the words are read one after the other and rewritten into their former state, between the computer access cycles.

The system described achieves reasonable efficiency for the gating amplifiers but requires a selection circuit capable of squeezing the appropriate pair of busses for a particular word. This could be accomplished by the customary diode matrix. For the "transformer-and-gate" matrix requires large standby currents. In this memory the squeezing busses call for relatively high currents; the resultant diode selection matrix is feasible but not practical because it draws a large amount of standby power. To avoid this, a selection matrix consisting of transformers and diodes is used which has no standby power requirement, although it does require more input drivers than would be necessary with a multidimensional diode matrix. For the "transformer-and-gate" matrix, developed at the NBS electronic computers laboratory, 2n inputs are required to select from n^2 words. The matrix is made up of two sets of crossing busses, X and Y; at each crossing a diode and transformer primary are connected in series, with the cathode of the diode tied to the X bus. Normally all of the X busses are held at +10 and all the Y busses at −10 volts. This puts backward bias on the diodes associated with each transformer, so that normally no current flows through any transformer. If one X bus is dropped to −10 volts, still no current flows; but if simultaneously one Y bus is raised to +10 volts, then just one transformer at the crossing of these two busses will receive a signal, the transformer secondaries connected to the diode-capacitor will squeeze the busses together, and the desired word will be selected.

Ruggedness

From the standpoint of ruggedness, the diode-capacitor memory is superior to the acoustic and cathode-ray tube memories. The components are light and non-microphonic, and no complicated mechanical problems exist. Printed circuit techniques may be used for the repetitious array, reducing assembly costs.

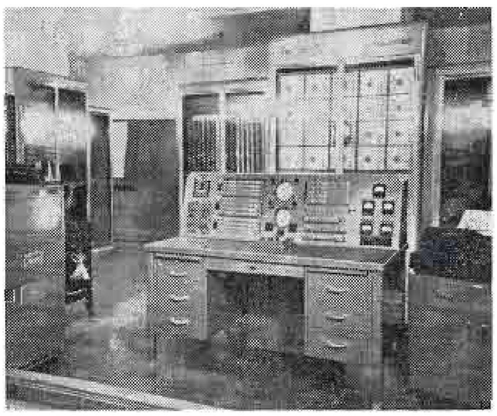
The complete repetition of the extremely simple basic circuit allows a new type of preventive maintenance. If the majority of failures have a single simple cause (low back resistance of a memory diode), a technique can be devised which will rapidly and thoroughly check for marginal diodes by means of a machine program. This routine loads the memory with a known pattern and then slows down the regeneration rate of the memory while checking for errors. Any cell which fails too soon will have its position typed out, and the cell can be replaced in a matter of seconds. The entire program could be run every hour, if necessary, without seriously detracting from computation time. Other types of marginal checks, such as voltage variation, are possible, but the regeneration check seems to be most direct.

Automatic Computer

(*Continued from page* 84)

SWAC parallel circuits transfer numbers and instructions almost instantly, within the time of a single pulse (about 0.1 μsec).

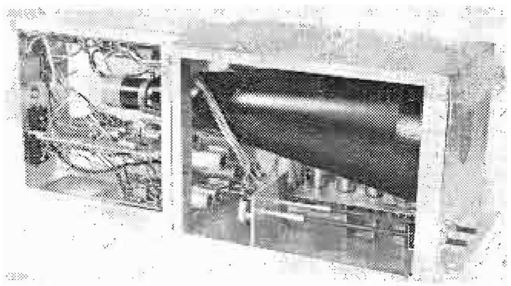
While the CRT type of memory delivers information at a very rapid rate, its capacity is limited by the number of digits that can be stored on the face of a single tube. To provide greater flexibility and computing power, a magnetic drum external memory was developed by R. Thorensen and associates of the NBS



Behind SWAC console is Williams memory, with control units on either side. Magnetic drum is at left, paper-tape input right of console

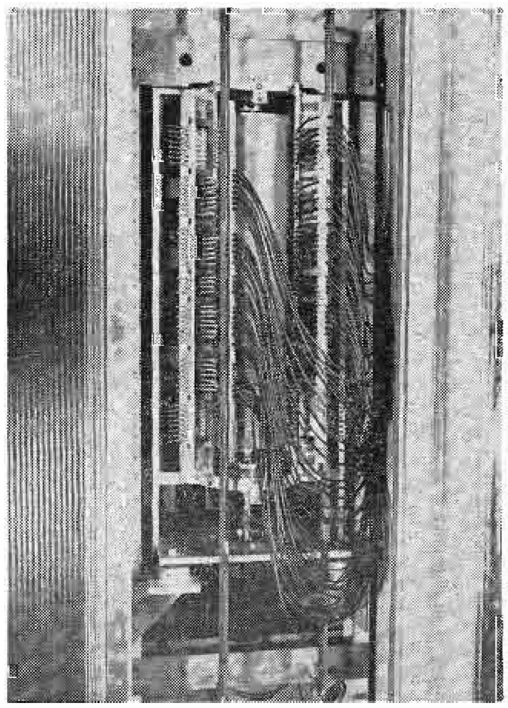
staff. SWAC's drum memory is a revolving metal drum which retains numbers and instructions on its surface in the form of magnetic pulses like those used in tape recording. At intervals, blocks of magnetic pulses are removed from the drum by a magnetic head and are taken into the computer to be transformed electronically into spots of charge in the Williams tube memory, where they remain until called for by the control unit.

SWAC stores and processes information in units called words, each word consisting of 37 binary digits, the equivalent of 11 decimal digits. The magnetic drum has a capacity of



One of 37 CRT's comprising Williams memory

4096 words of 37 binary digits each, in contrast with the 256-word capacity of the CRT memory. This high-capacity memory makes possible the solution of very large sets of simultaneous equations. Access time is shortened in two ways: (1) Numbers are transferred in sizable blocks from the magnetic drum memory to the cathode-ray tube memory, thus minimizing the total number of times the drum memory must be consulted. (2) The numbers in each of these blocks are stored sequentially around the circumference of the



Magnetic-drum auxiliary memory added to SWAC

drum so that one block forms a band or channel completely encircling the drum. When a transfer to or from the drum memory is made, the whole channel is handled at one time. Transfer of information starts immediately after the proper channel has been selected and continues for exactly one drum revolution thus eliminating all waiting time. In this way the access time per word is reduced to 500 μsec—about 1/30 of the normal access time of a magnetic drum memory.

The CRT memory operates in parallel with the serial magnetic drum memory, and the two are not in synchronism. Direct communication between the memories is therefore not possible. Information from the drum must first be played back into a vacuum-tube shifting register and then transferred in parallel to the cathode-ray tube memory. Each digit takes 13 μsec to play back, so the three empty digit spaces in each word give total delay of 39 μsec between words. This delay is more than adequate for transferring a number from the register to the CRT memory and for clearing the register to receive new information.

In addition to the drum memory, plans call for a slow-speed auxiliary memory consisting of a magnetic-tape unit. It will have a much larger capacity than the other two memories, holding approximately 4,000,000 binary digits, but its average access time will be quite long—about 3½ minutes.

Microwave Frequency

(*Continued from page* 84)

calibrated. The output of a frequency modulated local oscillator is admitted to the converter crystal through a directional coupler, where it is mixed with the standard signal.

The intermediate frequency from the converter is fed to a spectrum analyzer and the matching sections are adjusted for maximum signal strength. Attenuators placed on either side of the meter to be calibrated are set to 10 db each, which effectively isolates the calibrating equipment and prevents reactive "pulling" of the meter.

The frequency meter to be calibrated is set to resonance at each calibration frequency at least ten times. The divergence or spread of the readings at a given frequency is then a measure of the backlash or other mechanical defects of the drive and indicating mechanism. This spread is included in the calibration report as the tolerance to which the readings are reproducible.

Although not included in a normal calibration, it is possible to measure the cavity temperature coefficient of frequency near room temperature and the approximate "Q" of the cavity. The temperature coefficient is determined by observing the shift of resonant frequency at a fixed setting of the meter while the temperature is changed. Changes in cavity are monitored by a thermocouple junction attached to the meter. The Q of the cavity is determined by observing the half-power points on the response curve of the cavity for a signal which is frequency modulated through the resonance frequency.

Because the power of the harmonics used as standard-frequency signals is often as low as 1 microwatt, direct detection by means of a crystal diode and a sensitive current meter is usually impractical. In addition, the useful power at the detector is further reduced by a nominal insertion loss of 10 db for the transmission filter and 10 db each for the padding attenuators. The power available at the detector is then about 0.001 microwatt. Therefore, when a frequency meter with a built-in crystal detector is to be calibrated, a higher power CW oscillator is used and adjusted to the frequency of the standard signal. Amplification of the beat note between the standard signal and a small portion of the oscillator output is sufficiently high to permit the adjustment of the oscillator to the same frequency as the standard-frequency signal. The accompanying precision is decreased approximately one order of magnitude. The remainder of the oscillator power is sufficient to permit the crystal current from the detector to be monitored with a microammeter.

Sensitive Receiver Used

When the type of calibration is such that the standard frequency signal can be passed through the meter to be calibrated, a sensitive receiver is used to detect the signal. In the frequency range 300 to 750 MC a double superheterodyne panoramic receiver is employed; above 750 MC a sensitive spectrum analyzer detects the signal.

Direct reading local oscillators of the external cavity reflex klystron type generate the signals from 750 to 11,000 MC. Above 11,000 MC, internal cavity reflex klystrons, mounted directly on the waveguide connecting the meter to the standard, provide local oscillator power. Because the power of the local oscillator is much greater than that of the standard signal, the height of the pulse displayed is directly proportional to the power of the standard signal. The frequency meter being calibrated is tuned to resonance by observing the relative pulse height on the cathode ray tube of the analyzer. Voltage gains of 160 db are possible with the spectrum analyzer, which can then detect microwave signals as low as 0.1 micro-microwatts.

Fee Schedule

The fee schedule for NBS calibration of microwave frequency equipment is as follows: $33.00 to $42.00 for the first frequency calibration point, and $5.00 to $8.00 for each additional frequency calibration point depending on the type of secondary standard. More complete information may be obtained from NBS Circular 483, for sale by the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C. (price 25¢)

Mobile Field Units Check Interference

The problem of radio interference sometimes caused by industrial high frequency equipment is being handled at Thermatron Div., Radio Receptor Co., with the aid of uniquely equipped station wagons designed for mobility and speed. The test in-

struments in the vehicles are capable of making precise field measurements to determine compliance with Section 18 of F.C.C. regulations. The units are easily handled by two-man crews.

The cars have two antennas mounted on the top and two sets of instrumentation behind the driver's seat that cover the range from 15 MC to 300 MC. In order to allow the car to travel on all roads and without structural interference the low frequency antenna is an adjustable dipole mounted on a retractable mast. When in use, the mast is swung into vertical position. Controls at the base of the mast permit remote adjustment of azimuth and the plane of polarization. When not in use the mast is swung easily into horizontal position permitting the vehicle to travel. There is a two-way radiotelephone link between the field car and plant.

NBS DEVELOPMENTS (Continued)

"Obstacle Gain"

(*Continued from page* 85)

deciding influence on the future choice of sites for transmitting and booster station installations. For example, in a region of the country like Colorado, it may prove more advantageous to locate FM and TV stations at lower elevations a short distance out on the plains away from the mountains rather than on the foothills right up against the very high mountains of the continental divide.

Radio waves transmitted over the theoretical smooth spherical earth are considered to arrive at points within the radio horizon by virtue of a normal diffraction process and by scattering from the turbulent atmosphere. The turbulence, which is greatest near the earth's surface and decreases with increasing height into the upper atmosphere, is also considered responsible for the relatively weak and fading signals normally observed at distances well beyond the horizon. The obstacle gains associated with a properly situated knife-edge ridge have been found to be large enough to reduce the transmission loss accompanying the reception of these signals beyond the horizon, thereby effectively eliminating the fading associated with the atmospheric scattering process.

A mountainous obstacle extending well above both the transmitting and receiving antennas requires the radio waves to pass through the most turbulent and disturbing regions of the atmosphere at relatively high grazing angles. With these large grazing angles, the amount of energy, received from the highly turbulent regions in the screened lower portion of the atmosphere is effectively eliminated and so, in turn, is most of the tropospheric fading which normally exists on a non-obstructed path.

Preliminary studies of obstacle gain, the ratio of signal power with an obstacle in the path to that without it showed that a considerable increase in received signal strength should result when a large knife-edge obstacle is located at the midpoint of the transmission path.

A requirement of the obstacle-gain method for increasing signal strength is that the height of the obstruction must be greater than the elevation of the common horizon. For example, transmission losses will be considerably reduced at 100 MC if the obstacle knife-edge for a 150-mile circuit is at the mid point of the path and about 1300 feet above the surrounding terrain. Theoretically, a 30 db decreases in transmission loss results. The amount of reduction in transmission loss can be varied by different combinations of antenna heights, obstacle heights, and frequency.

One of the obstacle-gain experimental paths examined in detail was a 38-MC, 160-mile communication circuit between Yakutat and Gustavous, Alaska, operated by the CAA. The radio wave transmissions, which originated from and terminated at low-level installations (approximately 200 feet above sea level), passed over a 9000-foot ridge of Mt. Fairweather. On the basis of the existing smooth-earth diffraction theory for an unobstructed path, the calculated transmission loss for the circuit is 207 db. With obstacle-gain theory, however, and the assumption that Mt. Fairweather acts as a single 8775-foot knife edge, the expected transmission loss should be only 127 db. The experimental results showed the transmission loss was approximately 134 db, within 7 db of the value predicted by the knife-edge calculations. The transmission losses (127 and 134 db) correspond to a calculated obstacle gain of 80 db and a measured gain of 73 db, respectively, greater than the field strength normally expected when considering radio transmission over a smooth spherical earth.

Intermetallic Compounds

(*Continued from page* 86)

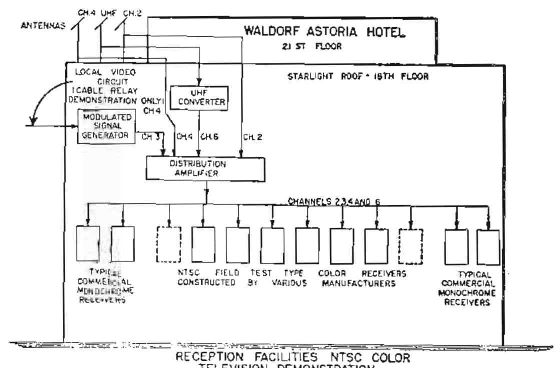
combinations with proper energy to yield the desired semiconductor characteristics.

NBS research on single crystals is aimed at the preparation of junction-type diodes and triodes, particularly the p-n junction diode—conduction first by holdes and then electrons. The performance of these devices, especially in regard to their power handling ability, is markedly superior to point contact units. In addition, the theory and practice, especially for diodes, is well understood. It is to be hoped that the improved ease of handling GaSb over Si will permit the preparation of a good high-temperature diode and eventually n-p-n transistors, although this last stage may be difficult.

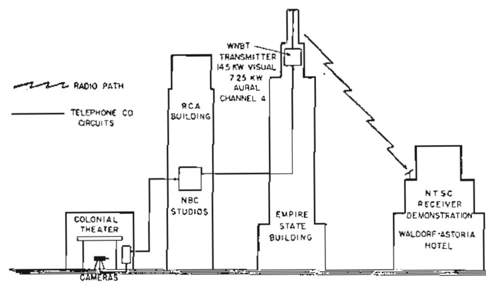
From a purely practical standpoint, the most important feature of the research program is the investigation of materials with equal or higher charge carrier mobilities than germanium.

NTSC Test and Demonstration Facilities

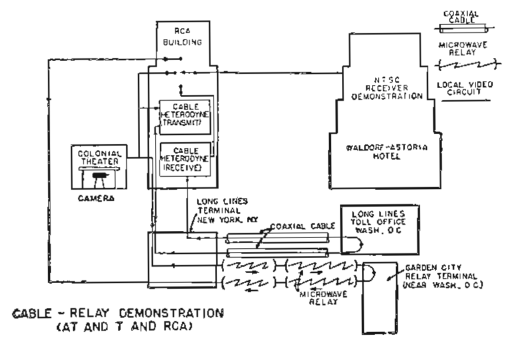
Showing to FCC in New York on Oct. 15, 1953. See related text on page 12, this issue.



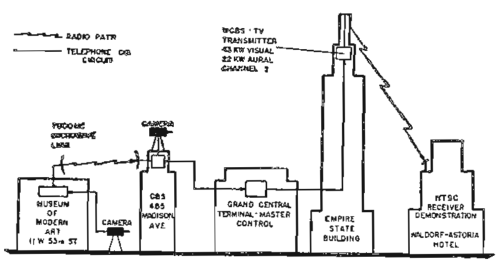
RECEPTION FACILITIES NTSC COLOR TELEVISION DEMONSTRATION



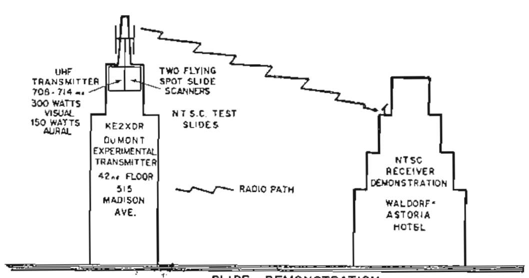
STUDIO DEMONSTRATION (RCA-NBC)



CABLE - RELAY DEMONSTRATION (AT AND T AND RCA)



OUTDOOR PICKUP DEMONSTRATION (CBS)



SLIDE DEMONSTRATION (DUMONT)

Microwave Directory

(*Continued from page 77*)

New London Instrument Co., New London, Conn., J. M. Duker, 3-8451, Test Equipment
Nichols Products Co., 325 West Main Street, Moorestown, N.J., E. B. Nichols, Jr., Moorestown 9-0877, Waveguides, Microwave Assemblies
N.R.K. Mfg. & Engineering Co., 4601 W. Addison St., Chicago 41, Ill., Frank Neukirch, SPring 7-2970, Microwave Assemblies, Radar Components
Panoramic Radio Products, Inc., 10 South Second Ave., Mount Vernon, N.Y., Bernard Schlessel, Mount Vernon 4-3970, Spectrum Analyzers
Pfleger Products, 3901 West 54th St., Los Angeles 43, Calif., Jack Long, AX 2-8313, Radar Parts
Phelps-Dodge Copper Prods. Corp., Styroflex Div., 40 Wall St., New York 5, N.Y., F. W. Lemly, WH 4-3570, Coaxial Cable
Philco Corp., Government & Industrial Div., 4700 Wissahickon Ave., Philadelphia 44, Pa., K. C. Moritz, TEnnessee 9-4000, Microwave Systems
Polarad Electronics Corp., 100 Metropolitan Ave., Brooklyn 11, N.Y., E. L. Henoch, STagg 2-3464, Microwave Receivers
Polytechnic Research & Development Co., 55 Johnson St., Brooklyn 1, N.Y., H. C. Nelson, ULster 2-6800, Microwave Test Equipment
Premier Instrument Corp., 52 West Houston St., New York 12, N.Y., J. K. Greenberg, Gramercy 5-3520, Waveguide Components
Press Wireless Laboratories, 25 Prospect Place, West Newton 65, Mass., N. F. Hoard, LAsell 7-5600, Microwave Test Equipment
Presto Recording Corp., Specialty Prod. Div., P.O. Box 500, Paramus, N.J., Diamond 3-5700, T. B. Aldrich, Microwave Frequency Standards
Prodelin. Inc., 307 Bergen Ave., Kearny, N.J., J. F. Cosgrove, KEarny 2-8600, Coax Lines, Waveguide, Antenna Towers
Radiation Inc., Melbourne, Fla., W. W. Dodgson, Jr., 800, Signal Generators
Radio Corp. of America, RCA Victor Div., Bldg. 15-2 Camden, N.J., R. C. Dubois, Woodlawn 3-800, Microwave Relay Systems
Radio Corp. of America, RCA Victor Div., Harrison, N.J., Fred Banko, HU 5-3900, Magnetrons, Pencil Type Triodes, UHF & Microwave Vacuum Tubes
Radio Engineering Labs., 36-40 37th St., Long Island City 1, N.Y., ST 6-2100, Joseph Behr, Communication Equipment
Radio Frequency Labs., Inc., Butler Road, Boonton, N.J. R. W. Seabury, Jr., BO 8-3100, Standards Equipment
Raytheon Mfg. Co., 138 River St., Waltham 54, Mass., Waltham 5-5860, Microwave Relay Link, Microwave Xmission Link, Radar, Tubes
Remler Co. Ltd., 2101 Bryant St., San Francisco 10, Calif., A. R. Ogilvie, VA 4-3435, Microwave Equipment
Resdel Engineering, 2309 Riverside Drive, Los Angeles 39, Calif., W. E. Osborne, OL 2955, Microwave Equipment
Sanders Associates Inc., 137 Canal St., Nashua, N.H., H. W. Pope, 5570, Custom Radar
Schutter Mfg. Co., Carl W., 80 E. Montauk Hwy., Lindenhurst, N.Y., Lindenhurst 5-2290, Radar Components, Waveguides
Selector Industries, Inc., 401 E. 138th St., New York City, W. E. Thompson, MO 5-4600, Waveguides
Sierra Electronic Corp., 1050 Brittan Ave., San Carlos Calif., T. F. Turner, LYtell 3-2104, Directional Couplers, Reflection Coefficient Meter
Sightmaster of California Co., Gillespie Airport, Santee, Calif., Samuel Freedman, Hilldale 4-7661, Microwave Calorimeters, Waveguides
Southern Electric and Transmission, 3127 Holmes St., HA 7131, Dallas, Texas, Microwave Equipment
Specialty Assembling & Packing Co., 79 Clifton Place, Brooklyn, N.Y., M. Cammer, UL-7-4760, Radar Receivers
Sperry Gyroscope Co., Div., The Sperry Corp., Great Neck, L.I., N.Y., W. J. Henderson, Fieldstone 7-3600, Test Equipment, Klystron Products
Stainless, Inc., Third St., North Wales, Pa., L. Guzewicz, Towers
Sylvania Electric Products Inc., Woburn, Mass., E. H. Ulm, Tubes, TR & ATR, Magnetrons, Rocket Tubes, Klystrons, Crystals
Technicraft Laboratories, Thomaston-Waterbury Rd., Thomaston, Conn., G. R. Houk, Waveguides
Telechrome, Inc., 88 Merrick Rd., Amityville, L.I., N.Y., H. R. Clark, AMityville 4-4446, Microwave Noise Generators
Telemarine Communications Co., 3040 W. 21st St., Brooklyn, N.Y., J. Bernsley, Microwave Equipment
Telescreen Corp., 36 Grove St., New Canaan, Conn., W. L. Norvell, New Canaan 9-9553, Radar Beacons
Telewave Laboratories, Inc., 100 Metropolitan Ave., Brooklyn, N.Y., E. L. Henich, ST 2-3464, Components for Microwaves
Terpening Co., L. H., 16 W. 61st St., New York, N.Y., L. H. Terpening, CI 6-4760, Microwave Equipment
Thompson Products, Inc., 2196 Clarkwood Rd., Cleveland 3, Ohio, F. J. Weihmiller, HE 1-6765, Microwave Components, Coaxial Switches
Titeflex, Inc., 500 Freylinghuysen Ave., Newark 5, N.J. G. T. Wygant, Bigelow 3-0600, Waveguides
Torngren Co., C. W., 236 Pearl St., Somerville, Mass., H. A. Harvey, MO-6-3250, Transmitting Reflectors
Tower Construction Co., 1923 Geneva St., Sioux City, Iowa, M. N. Lasensky, 5-6761, Microwave Towers, Reflectors
Trad Television Co., 1001 First Ave., Asbury Park, N.J., R. Edwards, Asbury Park 2-7445, Attenuators, SWR Indicators
Transitron Inc., 154 Spring St., New York 12, N.Y., S. K. Lackoff, WOrth 4-8739, Microwave Signal Generators
Transmitter Equipment Mfg. Co., Inc., 35 Ryerson St., Brooklyn 5, N.Y., M. B. Kahn, Transmitters
Trilsch Co., John D., 1310 McKinney Ave., Houston 2, Texas, J. D. Trilsch, ATwood 9351, Microwave Towers
Tru-Connector Corp., 416 Union St., Lynn, Mass., R. P. Grant, Ly 8-9379, Co-axial Connectors

MICROWAVE DIRECTORY (Continued)

Truscon Steel Div., Republic Steel Corp., Albert St., Youngstown L, Ohio, G. F. Bateson Sr., Riverside 6-7211, Microwave Towers

Up-Right, Inc., 1013 Pardee St., Berkeley, Calif., Towers

U. S. Components, Inc., 454 E. 148th St., New York 55, N.Y., B. A. Jackson, CY 2-6525, Microwave Components

U. S. Tower, Union Trust Bldg., Petersburg, Va.

Universal Mfg. Co., Microwave Div., 410 Hillside Ave., Hillside, N.J., W. J. Dolan, Waverly 6-4141, Waveguides, Microwave Components

Varian Associates, 611 Hansen Way, Palo Alto, Calif., W. M. Silhavy, DAvenport 5-5631, Microwave Tubes, Klystrons

Vectron, Inc., 400 Main St., Waltham, Mass., Stuart Gibson, WAltham 5-8700, Spectrum Analyzers

Waveline, Inc., Passaic Ave., Caldwell Township, N.J., R. H. Koenig, CAldwell 6-5785, Microwave Instruments

Weinschel Eng. & Mfg. Co., 10513 Metropolitan Ave., Kensington, Md., B. O. Weinschel, Attenuators

Western Mfg., 140 W. 22 St., Kearny, Nebr., Microwave Equipment

Westinghouse Electric Corp., 2519 Wilkens Ave., Baltimore 3, Md., C. L. Suhrstedt, EDmundson 6-2300, Microwave Relay Links

Westinghouse Electric Corp., Box 284, Elmira, N.Y., Joseph Schlig, Microwave Tubes

Weston Electrical Instrument Corp., 614 Frelinghuysen Ave., Newark, N.J., E. Higgins, BI 3-4700, Instruments

Weymouth Instrument Co., 1440 Commercial St., E. Weymouth 89, Mass., R. L. Tedesco, WE 9-2404, Microwave Equipment

Wheeler Laboratories, 122 Cutter Mill Rd., Great Neck, N.Y., David Dettinger, Great Neck 2-7806, Custom Microwave Components

White & Son, James L., 374 Verona Ave., Newark, N.J., James White, HU 2-3727, Coaxial Antennas

Wincharger Corp., E. 7th & Division Sts., Sioux City, Iowa, J. V. Holmes, Towers

Wind Turbine Co., E. Market St., W. Chester, Pa., D. B. Oat, Power Plants

Workshop Associates Div., Gabriel Co., Endicott St., Norwood, Mass., C. R. Lane, NOrwood 7-3300, Microwave Antennas

CBS TV Tube

(*Continued from page* 73)

by the deflection angle employed in the tube so as to overcome the convergence effect at the raster edges. When mounted the mask is spaced approximately 0.4 in. from the tube face-plate on which the phosphor triads have been deposited. In this construction no stretching of the mask is required and the mask itself, containing 250,000 holes each 0.009-in. in diameter, is fabricated using well-known metal stamping techniques.

In the planer color mask tube the three color phosphor triads are deposited on the planar glass plate by a silk screen process. In the Colortron a photoengraving technique is employed and the color triads are deposited directly on the face-plate of the tube rather than on a separate glass plate. In manufacture the first color phosphor is laid down on the tube face-plate. Then the color mask is inserted and the photosensitive phosphor emulsion is exposed to light which emanates from the position that one of the three electron guns will take in final assembly. The color mask is removed and the phosphor surface is then "developed." The complete process is repeated for each of the other two colors.

The 15-in. Colortrons demonstrated on a closed TV circuit using

(*Continued on page* 165)

Servo Design

(*Continued from page 76*)

outputs of the intelligence device should be superimposed on the commands. Any of these combinations will prove more realistic than the sinusoidal frequencies assumed in the first analysis.

From the data of these computer runs we can determine a gain setting or gain program for the servo that will yield the required stability and accuracy over the entire flight. In addition, we obtain the value of the largest time constant which can be allowed the servo without adversely affecting overall performance. These figures comprise a set of specifications for the servo design which greatly influence the choice of hardware. However, the specifications are set up on the basis of an ideal linear system. The adverse or beneficial results of non-linearities in the real system are yet to be found.

In order to make final choice of the servo hardware, we must consider the power requirements. The peak power needed to move the controls determines the rating of the actuator and often its generic type, while the average power influences the nature of the power source. To determine the peak power we must know the velocity and acceleration of the control surfaces and the moments opposing this motion. The control surface motion can be determined from the analog computer records. The opposing moments are due to the inertia, friction and damping, and to the aerodynamic hinge moment, which can be computed from the control surface design.

Hinge Moment

The hinge moment is nominally considered to be a linear function of control surface position for a given Mach number, although it may often deviate very much from this simple relationship, both by deliberate design and through influence of the airframe angle of attack. At this point, there exists a good opportunity for the flight control servo design to feed back into the aerodynamic design. If the hinge moments or inertias appear out of line, a substantial saving in servo power or weight can be obtained by redesigning the control surfaces.

It must be noted that the relation between hinge moment and control deflection, even when linear, varies widely with flight Mach number. Hence during a given flight, it may

SERVO DESIGN (Continued)

become zero or even negative—that is, it may tend to increase rather than decrease the control deflection. However, in estimating the peak power, we are interested only in the region where its product with control surface velocity is at a maximum.

Having investigated the peak power, we can often specify not only the kind of actuator, but its size and the size of all elements directly handling the output, such as bellcranks, gears, or torque tubes.

With the peak power specified, the average power and time of flight together determine the size and weight of the power source and power generating elements, for example, the batteries, hydraulic or pneumatic accumulators, and pumps. The average power will, of course, vary with each flight. It is almost impossible to determine with high accuracy without a complete program of flight simulation, or experience with actual flight of similar airframes. However, it is possible to make a close guess by estimating the power for a typical maneuver from the computer analysis, estimating the frequency of the maneuvers by reference to the mission of the airframe, and multiplying the resulting average power by a suitable safety factor. In the final design, these estimates must be checked and rechecked by flight stimulation or by flight test.

Choosing Types

Armed with the estimate of peak power, average power, time constant, and loop gain, the designer is in a position to choose between the various types of servomechanisms for the flight control. The types in general use include hydraulic, pneumatic and electrical, either motor or clutch. Each may be used in conjunction with magnetic or conventional electronic amplifiers. For the range of frequencies and power required in the average high performance missile or aircraft a hydraulic servo will often prove to be most suitable. Although there are some difficulties associated with hydraulic equipment, they have many advantages over electrical actuators—primarily in their frequency response and acceleration capabilities. A hydraulic system also has the advantage that less power is required to sustain a large hinge moment. They are preferred over pneumatic systems owing to the time lags and elastance of the latter. Present-day hydraulic servo-motors of high performance are much reduced in size over earlier designs, thus increasing their usefulness in aircraft. A typical example, shown in Fig. 3, is the unit made by Midwest Geophysical Lab., Tulsa, Okla.

The final choice is made not only on the factors mentioned, but on such additional considerations as availability of transducers in the power ranges desired, and availability of prime power from other sources. For example, a missile containing a great deal of electrical equipment may influence choice of an electrical system, while the availability of a source of high-pressure gas may tend to suggest a pneumatic system.

Laboratory Model

At this point, sufficient information is available to choose detailed components and to construct a laboratory model of the flight control servo. The mechanical model will include many time lags and non-linearities which were not considered in the analytical work. For this reason, a fairly lengthy program of compensation is required to complete the second-order design of the servo amplifier or controller. The method used is a step-by-step investigation of servo and airframe stability for many points on the flight path. The completed servo model is provided with spring and inertia loads simulating the real control surface reaction forces and its output shaft coupled electrically to the computer analog of the airframe. Using a flexible breadboard model of the amplifier, such as that shown in Fig. 4, the compensation can proceed under simulated flight conditions, utilizing step-function inputs as a test. In general, an attempt is made to find gain settings and compensation networks giving the necessary airframe response without incurring instabilities or exceeding certain overshoot criteria. When the design is considered complete, final tests are conducted with the flyable configuration of the servo amplifier, which as in Fig. 5, may differ considerably in size, shape, and complexity from the simple breadboard model.

With a more refined computer set-up it is possible to achieve a better design by taking advantage of a different concept of stability. If the coefficients of the kinematic and aerodynamic equations are suitably mechanized in the computer so as to vary automatically with the changing geometry and flight conditions, it is possible to duplicate realistically and in real time the entire

CORE MATERIALS (Continued)

controlled flight. It may be found that some combinations of servo parameters which apparently lead to instability or to inaccurate steering in the step-by-step analysis, now give satisfactory performance. With a higher degree of realism in the simulation, we may find it possible to achieve the desired results with cheaper or lighter components, even though arbitrary stability tests proved them unsuitable.

A typical example of such a complex analog computer set-up, in which the missile flight can be simulated is shown in Fig. 6 (photo courtesy of Reeves Instrument Co.). In this laboratory set-up, which represents a portion of Project "Cyclone," realism is carried to the extent that an entire missile can be tested intact, so that even the effects of signal lead lengths and cross-coupling on dynamic performance can be observed and measured. Thus, the whole missile system can be tested as an entity.

We have attempted to show how in each stage of the flight control servo design from its inception and specification to the detailed compensation of the components, systems considerations—aerodynamic and mechanical—are of equal importance to the electronic aspects. Although the airborne equipment designer is forced to this conclusion by hard facts, his counterpart in industrial controller design can profit by his experience, even when his task is inherently less demanding.

This paper was presented at the 1953 IRE National Convention, March 23-26, in New York City.

Conelrad Test Successfully Confusing

A nation-wide test to determine the effectiveness of the Conelrad civil defense system of controlling broadcast operations has proved successful. Under this system, only co-operating AM stations would be allowed to operate on 640 and 1240 KC during an actual air alert. TV, FM and non-cooperating AM stations would go off the air.

During the recent test all stations were allowed to continue operation, resulting in interference in some localities. However, aerial observers were successfully confused and unable to get a fix on any station. To date, some 1300 of the nation's 2100 AM stations have voluntarily spent $2,500,000 for Conelrad equipment. Details on how Conelrad operates are given in the March 1953 issue of TELE-TECH & ELECTRONIC INDUSTRIES, page 85.

Core Materials

(Continued from page 94)

is attributed to the permeability, that is, if the permeability is treated as a complex magnitude. In complex notation, the permeability has been given the form:

$$\vec{\mu} = \mu_L - j\,\mu_R \qquad (6)$$

where μ_L is an inductive component which so far has been referred to simply as permeability, and μ_R is a resistive component. (instead of μ_L and μ_R, symbols μ' and μ'' are frequently used and will appear in that form in the new American Standard Association definition of electrical terms, according to a communication from P. H. Haas of National Bureau of Standards.) With this complex permeability μ, Eq. (4) has to be written simply as follows:

$$Z_m = ja\,\vec{\mu}\,N^2\,A/l \qquad (7)$$

Obviously, then otation of a complex permeability does not describe an ew phenomenon in core materials. The usage of this notation is practical, not only because it alows the formal use of Eq. (5), but because it comprises all of the core characteristics represented in Figs. 6, 7, and 8. From Eq. (4) and (7) follows:

$$\vec{\mu} = \frac{R_m + ja\,L_m}{jaN^2\,(A/l)} = \frac{L_m}{N^2\,(A/l)} - j\,\frac{R_m}{\omega\,N^2\,(A/l)} \qquad (8)$$

Equating (8) with (6) gives:

$$\vec{\mu} = \mu_L - j\,\mu_R = \frac{L_n}{N^2\,(A/l)} - j\,\frac{R_m}{\omega\,N^2\,(A/l)} \qquad (9)$$

This result serves to illustrate the components μ_L and μ_R which read:

$$\mu_L = \frac{L_n}{N^2\,(A/l)} \qquad (10)$$

and

$$\mu_R = \frac{R_m}{\mu\,N^2\,(A/l)} \qquad (11$$

In Fig. 8, μ_L is represented.

The dissipation factor $D = R_m/\omega L_m$ derives from (10) and (11) as:

$$R_m/\omega L_m = \mu_R/\mu_L \qquad (12)$$

The characteristics of Fig. 7 derive from Eq. (12) as $R_m/\mu\omega L = \mu_R/\mu^2_L$ because μ, in conventional usage, is identical with μ_L in vector notation.

The complex permeability lends itself well to illustrate the figure of merit μ_R/μ^2_L as plotted in Fig. 7. Again, as in Fig. 5, loci can be de-

CORE MATERIALS (Continued)

rived representing equal μ_R/μ^2_L values. The equation μ_R/μ^2_L = Constant yields parabolas as shown in Fig. 9. This diagram reveals the limitations of the factor μ_R/μ^2_L for material evaluation. Again, as with Fig. 5, the question, "which materials are rated equal," can be answered. Materials with loss angles of higher than 45° should be excluded because μ_R increases at a higher rate than μ_L. Loss angles, δ, of 45° or higher do not occur in practical core materials, and it can be concluded that the factor $D_m/\mu = \mu_R/\mu^2_L$, as plotted in Fig. 7, gives a satisfactory general rating of core materials.

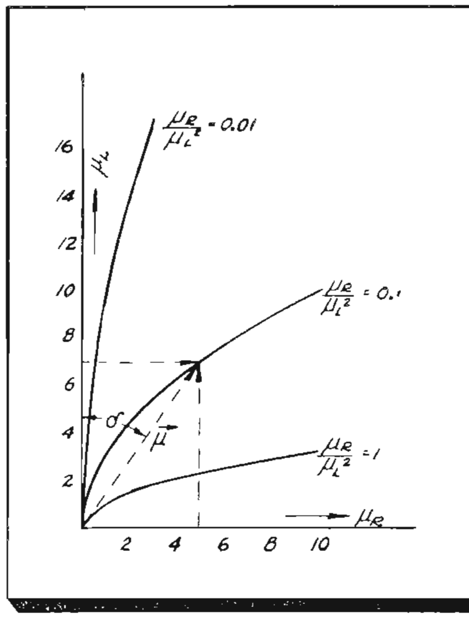


Fig. 9: Loci of vectors with equal merit

The author wishes to achieve the cooperation of the companies listed in Tables I and II for submitting information. Particular appreciation is extended to Messrs. G. H. Cole, D. C. Dieterly, and M F Littmann from the Armco Research Labs. and to Mr. W. Stifler from the Ferroxcube Corp. for special communications.

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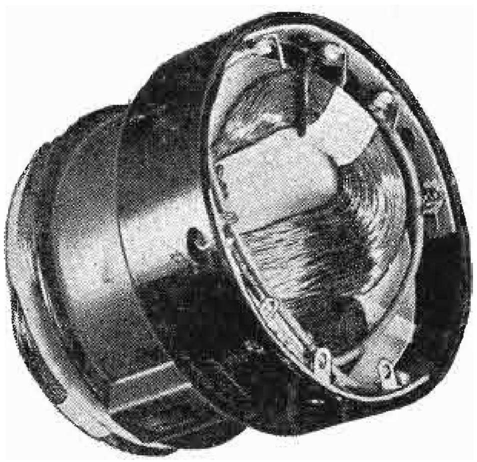
"Carcinotron"

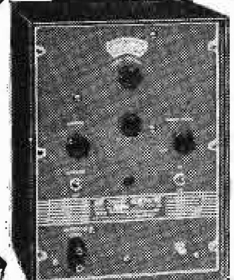
(*Continued from page* 66)

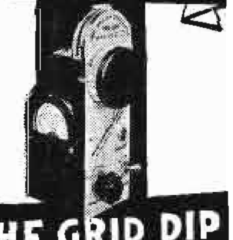
ergy is removed at the end of the line near the electron gun, the other end being terminated in such a way as to avoid multiple reflections between the two extremities of the line."

Fig. 2 illustrates the essential elements of the type M tube. These comprise:

1. A periodic waveguide anode structure "L" serving to transmit a wave with energy velocity v_g directed toward the left of figure, and having a "reverse" wave with phase velocity v_K directed toward the right. This structure is biased to a positive potential V with respect to the opposing plane electrode (grounded).
2. An electrode parallel to the anode structure and spaced from it by a distance d, biased to negative (ground) potential. This electrode, termed the "sole", together with the anode, serve to bound the interaction space.
3. An electron gun comprising a cathode "K" as an electron source.
4. An electron beam "F" injected from the gun through the interaction space along an equipotential V_o defined by $V_o = m\ v_e^2/2e$ where $v_e = v_K$.
5. A positively biased electron-collecting electrode (not shown) at the end of the system for the purpose of collecting the electrons which are not captured by the anode.
6. A terminating attenuating section "A" at the collector end of the delay line.
7. An r-f output system connecting the gun end of the delay line to an external load.
8. A magnetic field "B" normal to the plane of the drawing, uniform throughout the interaction space. When the beam current is increased above the critical value Ia given in







Eq. (9),[12] the system begins to oscillate at a wavelength determined by the point on the dispersion curve where $v_e = v_K$ for a reverse wave. Now v_e is the average translational electron velocity and is equal to E/B in the system of Fig. 2d. The continuous field, E, between anode and sole is equal to V/d. It can be seen therefore that as V is varied, the electron velocity varies, and the wavelength of oscillation varies accordingly.

The frequency of oscillation is determined by the dispersion of the delay line and the electron velocity. It is substantially independent of external rf loading of the tube. The power reaching the load is modified, however, in accordance with the power reflection factor of the load. As an example, for a 5.8 to 1 load voltage standing wave ratio (VSWR) half the power is absorbed by the load, and half is reflected.

As the electron beam gives energy to the rf wave on the anode, it loses potential energy and maintains the same translational velocity v_e. It is injected into the system along an

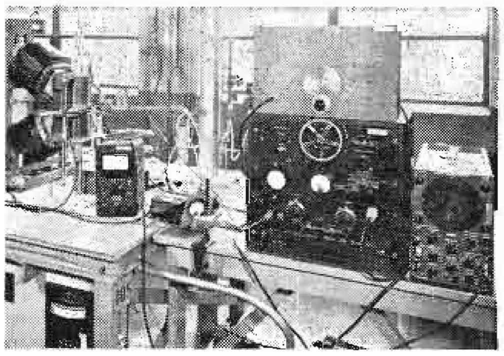


Fig. 9: Lab set-up for measuring performance

equipotential V_o, and as it exchanges energy with the wave it moves through successively higher equipotentials until it is captured by the anode at potential V. The electronic efficiency of the system η_e is given, as a first approximation by the relation:

$$\eta_e = 1 - V_o/V \qquad (10)$$

It is possible to design a tube so that V is of the order of 5 times V_o, yielding a theoretical electronic efficiency of 80 percent. Eq. (10) assumes ideal linear electron trajectories. If one considers the most undesirable trajectories, i.e., cycloidal trajectories, Eq. (10) becomes:

$$\eta = 1 - 4V_o/V \qquad (11)$$

and the efficiency would be 20% for the case just cited.

In practice, the electronic efficiency is a function of the linearity achieved in the electron trajectories. It is further modified by space charge (diocotron) effects [2,10], and the fact that some of the electrons are captured by the sole and collector.

Overall efficiency of the tube is determined by electronic efficiency and losses in the delay line circuit. Tubes operating at S-band with an overall efficiency of 50% have been reported.[2]

Experimental Tube

Fig. 3 illustrates a circular experimental M type oscillator designed for operation in the frequency range from about 2000 to 3000 MC. While the foregoing discussions were concerned with a linear model for simplicity, it is nevertheless possible to construct such tubes in a compact circular form, with appropriate modifications. The diameter of the envelope is 4.5 in.; the thickness (which defines the magnet gap) is 1.8 in.; the overall height including the bushing is 10.25 in. The weight is 7 lbs. without magnet. The tube was operated in the laboratory using external pole pieces and an electromagnet.

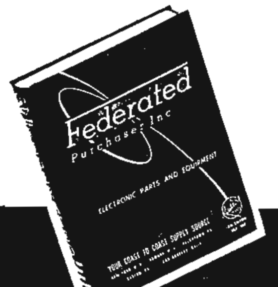
The r-f output was connected to the load by means of a 7/8 in. coaxial 46-ohm line, using standard fittings. Water cooling was required and was provided by the temporary expedient of a loop of tubing brazed to the cylindrical envelope.

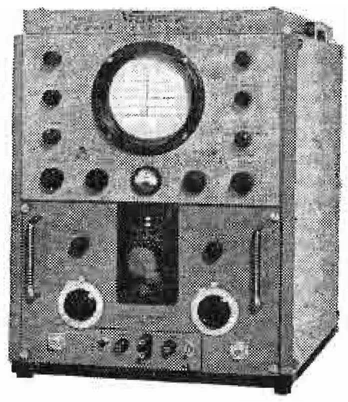
The internal construction of the tube is displayed in Fig. 4 where the cover, bushing and sole assembly have been removed from the body of the tube, exposing the periodic anode structure.

Measurements made during the course of development of this tube included measurement of the dispersion characteristics of the delay line, measurement of impedance match between the delay line and the external coaxial line, measurement of attenuation introduced at the collector end, and measurement of the r-f characteristics looking into the output of the completed tube.

Fig. 5 shows the dispersion characteristics of the delay line determined by exciting the anode from an r-f source and probing the field pattern. Comparative data is shown which was determined by operating the tube and performing a calculation using the E/B relationship. Substantial agreement was obtained between the two methods within the limits of experimental error.

The coaxial output line was matched to the delay line by means of a quarter-wave transformer section. Fig. 6 shows the degree of im-





pedance matching obtained by this method. This data was computed from measurements made on a linear delay line having essentially the same characteristics as that used in the tube. The VSWR was measured looking into the output pipe, while the line was terminated through an identical pipe to a matched coaxial load. This linear model was also used for measurement of the amount of attenuation α introduced at the collector end as a function of frequency. Results of these measurements are plotted in Fig. 7. The attenuation was undesirably low at the lower frequencies.

The decibel standing wave ratio characteristic looking into the completed tube is shown in Fig. 8. It will be observed that the impedance match had deteriorated in comparison to that originally obtained (Fig. 6) between the coaxial line and anode delay line. This deterioration is caused by reflections from both ends of the attenuating section at the lower frequencies and by reflections from the first end at the higher frequencies. More attenuation at the lower frequencies would eliminate one of the reflections.

Operation of the Tube

The completed tube was operated while being continuously pumped. Fig. 9 shows the tube in position between the magnet pole pieces at the left. High frequency power was measured by the water load, which can be seen joined to the coaxial output connection of the tube. Magnetic field strength was measured by the commercial type gaussmeter on the table just to the right of the tube. On the right of this is a meter lying flat on the table which measures temperature rise (by means of thermo couples) of the controlled flow of water in the load. The meter on the right of the thermocouple meter is the indicator for an absorption type wavemeter clamped to the edge of the table on the right. The large instrument in the center of the right table is a spectrum analyzer, while the oscilloscope at the right end was used for recording dynamic frequency versus anode voltage operation. Power supplies for the tube do not appear in the photograph.

Static measurements of power output and frequency were made as a function of anode voltage at a constant beam current of 165 ma, beginning at a voltage of four kilovolts and increasing in intervals to 6 kv, where arcing occurred which damaged the uniformity of the anode delay line. These results are shown in Fig. 10. Over this range of voltage, continuous tuning of frequency was obtained from 2270 to 2850 MC with no discontinuities. As far as could be determined, the tube operated at only one frequency for a given anode voltage. At a frequency of 2300 MC, a power output of 200 watts and an overall efficiency of 29.2% was recorded. The magnetic field in the interaction space was 1230 gauss.

Provision was made for frequency modulating the tube by adding a 60-cycle voltage to the continuous anode voltage, and sweeping the horizontal deflection of a cathode ray oscilloscope trace simultaneously at at 60-cycle rate; the r-f output of

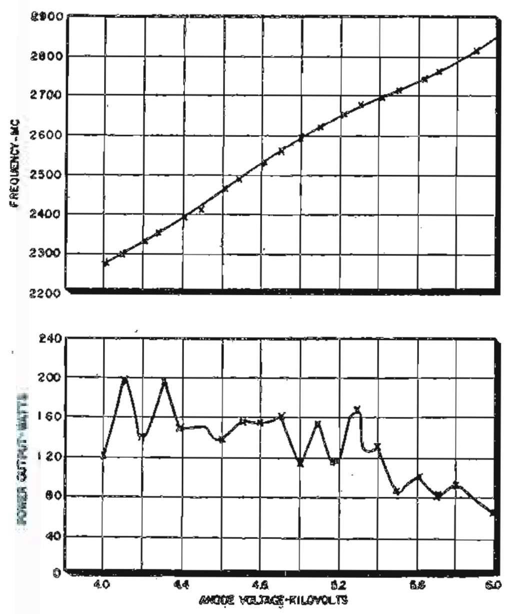


Fig. 10: Voltage-tuned oscillator performance

the tube was detected by the crystal wavemeter and amplified. Its signal was used for the vertical deflection of the oscilloscope trace. In this way, power vs voltage was plotted dynamically. Since frequency was determined by the anode voltage, this plot was also a power vs frequency display. The extent of frequency deviation was determined by observing a pip introduced in the display when the frequency equalled the resonant frequency of the wavemeter. By this method, voltage tuning over the range from 1624 to 2740 MC was recorded, with power output dropping to small values at the low frequency end of the range.

The effect of load variations on frequency was measured. Discontinuities causing a predetermined standing wave ratio were introduced in the coaxial line between the tube and the load. These discontinuities were moved through all phase positions, while their effect on frequency (pulling) was observed. The tube was operated at a frequency of 2300 MC during this test. The variation of

"CARCINOTRON" (Continued)

frequency was influenced to a certain extent by fluctuations in the magnet and anode power supplies, so that the measurements are here reported as maxima. In reality the true pulling figure may be somewhat less. For a 1.5/1 VSWR load in all phase positions the pulling was less than 1 MC; at 2.5/1 VSWR it was less than 2 MC, and at 3.5/1 it was less than 2.5 MC

Conclusion

The elementary theory of a backward wave oscillator with a transverse magnetic field has been presented. Theory predicts such tubes should have several desirable features. These, observed in the operation of an experimental model and reported above, were as follows:

1. Power output of the order of hundreds of watts at microwave frequencies.
2. High efficiency.
3. Electronic tuning over a wide band by variation of anode voltage.
4. Capability of rapid tuning and frequency moduluation by use of the electronic tuning feature.
5. Insensitivity to load variations (i.e., low pulling figure).

The Carcinotron described in this paper is a report of the preliminary results in the U. S. of a co-operative effort in this field between the Compagnie Générale de Télégraphie Sans Fil (CSF) of Paris, France, and the Raytheon Manufacturing Co. This project is supported by the U. S. Signal Corps.

We wish to acknowledge our thanks to those in the Electron Tube Research Laboratories of CSF: Messrs. R. Warnecke, P. Guénard, O. Doehler, G. Mourier, to name a few, as well as those in our own laboratories who are contributing their effort in this work. We further wish to extend our appreciation to the late Dr. Gorham, as well as to Messrs. G. R. Kilgore and J. Hull of the Signal Corps, whose foresight and interest have materially aided the introduction of this development in the U. S.

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905 **Precision Paper Tube Co.** Coil bobbins
906 **Premier Instrument Corp.** Waveguide components
907 **Presto Recording Corp.** Microwave secondary frequency standard
908 **Proceedings of the I.R.E.** Special issue on color TV
909 **Prodelin Inc.** Coaxial transmission lines
910 **Radio Corp. of America** Engineering personnel
911 **Radio Corp. of America** Microwave relays
912 **Radio Corp. of America** Electron tubes
913 **Radio Corp. of America** UHF pylon antenna
914 **Radio Materials Corp.** Ceramic capacitors
915 **Radio Receptor Co., Inc.** Germanium diodes
916 **Raypar Inc.** Transformers for printed circuits
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11. E. C. Dench, "Progress in the United States on the M Type Carcinotron," paper presented at the Eleventh Annual Conference on Electron Devices, Stanford Uni.; June 18-19, 1953.
12. Eq. (9) was derived neglecting space charge effects and serves to give an order of magnitude of the current for starting of oscillations. This current is modified by an effect termed the "diocotron" effect, which is due to space charge amplification within the electron beam. Phenomena believed to be related to this effect have been observed by the author in smooth bore cylindrical magnetron diodes.

CBS TV Tube

(*Continued from page* 150)

NTSC slides as a signal source employed 45° deflection angles. The tube measured 26⅛ in. overall and weighs approximately 18.5 lbs. The electrostatic-focus electron guns employed were each similar to those used in type 5TP4 projection-type black-and-white tubes. High voltage requirements for the tubes are: 20,000 volts with maximum current drain of 60 μamps; convergence electrode 9,300 volts with maximum drain of 5 μamps; focus electrode 3,100 volts with a maximum current drain of 40 μamps. The regulation of the anode and convergence voltages must remain within 2% to prevent misregistration.

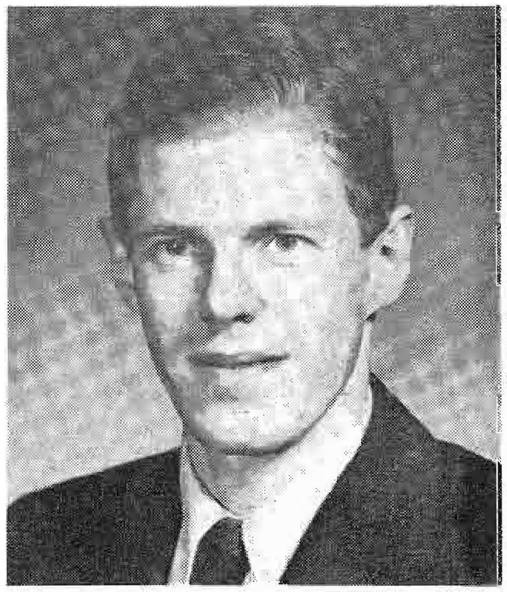
Engineers who were responsible for this development include: Charles F. Stromeyer, Vice President, Engineering & Manufacturing; Dr. Russell R. Law, Technical Advisor, Research & Development; Norman F. Fyler, who directed laboratory staff; William E. Rowe, photographic techniques of tri-color screen fabrication; Clifford W. Cain, Laboratory Instrumentation; Robert B. Tomer, Director Commercial Engineering; Herber G. Ryan; evaluation of color tube designs; and Elwood W. Schafer who directed transition of the design from laboratory to pilot production.

Columbia Broadcasting System Inc., parent organization to CBS-Hytron have also announced the development of a color TV "Chromacoder" studio camera system. This camera employs one image orthicon with a rotating field-sequential color disc. The camera output is fed to a Chromacoder picture tube which is viewed by three vidicons. A shutter synchronized with the color fields permits each vidicon to view just the color for which it is intended (i.e., red, green or blue). The vidicon decay characteristic allows the color picture to be stored until the next same-color field is displayed. In this manner, the field-sequential output of the camera is transformed into a compatible NTSC simultaneous signal, and then sent to the transmitter.

PERSONAL

Robert D. Hallock has been appointed plant manager in charge of engineering and production for American Microphone Co., Pasadena, Calif. Prior to joining his present company, Mr. Hallock was associated with Bardwell & McAllister, Inc., Solar Mfg. Corp., Standard Coil Products Co., and Airesearch Mfg. Co., as design engineer, chief engineer, and plant manager in the electronic divisions of these companies.

Dr. George Cheney Newton, Jr., associate director, Servomechanism Laboratory, MIT, was awarded the Louis E. Levy Medal by The Franklin Institute of the State of Pennsylvania for his paper, "Compensation of Feed-back-Control-Systems." Presentation was made in Franklin Hall, October 21, on the occasion of the Institute's annual Medal Day ceremonies.



Dr. G. C. Newton, Jr.

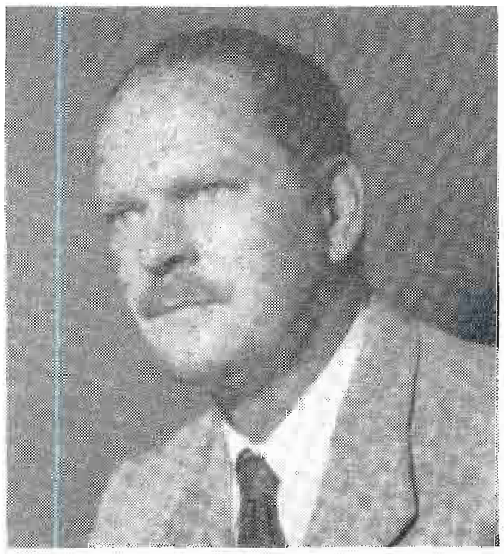
John L. Ham has been appointed director of the metallurgical department of the National Research Corp., Cambridge, Mass. **James H. Moore**, who formerly held the position, has become general manager of the company's wholly-owned subsidiary, Vacuum Metals Corp.

William A. Wagner, formerly chief divisional designer for Montgomery Ward & Co., has been appointed chief product designer for Warwick Manufacturing Corp., Chicago, Ill., radio and television manufacturer.

Dr. Louis T. Rader has been appointed general manager of a specialty control department at General Electric Company's Schenectady (N.Y.) works, a new department that will be largely responsible for industrial electronic, regulator, and aircraft control equipment. Recently, Dr. Rader announced the following appointments to his staff:

K. N. Bush, manager of manufacturing; H. L. Palmer, manager of engineering; and C. S. Van Wormer, manager of finance. Before his return to G-E in 1949 to manage the engineering laboratory of the control division, Dr. Rader was head of the Electrical Engineering Department at the Illinois Institute of Technology.

Kenneth B. Boothe, vice-president and director of instrumentation and sales for Audio & Video Products Corp. has been elected a director of the company, as were **Martin V. Kiebert, Jr.**, **Bernard B. Smith**, and **Irving M. Buckley**. During World War II, Mr. Boothe was chief of telecommunications for the Psychological Warfare Branch of the Allied Military Forces in the middle East and the Balkans. From 1943 to 1944, he served as communications attache for the United States Embassy in the Soviet Union.



Kenneth B. Boothe

Dr. George M. Anderson has been named head of the Engineering Development group at Edison Laboratory to reduce to working models new products and product-improvement research being conducted in the new laboratory in physical, chemical, and analytical fields. From 1951 until he joined the Edison Laboratory staff, Dr. Anderson worked on the development of the atomic reactor for submarine propulsion at the Westinghouse Atomic Power Division in Pittsburgh, Pa.

Howard O. Meuche has been appointed production superintendent of Sterling Engineering Co., Inc., Laconia, N. H., electrical relay manufacturing subsidiary of American Machine & Foundry Company. Prior to joining Sterling, Mr. Meuche was assistant plant manager of National Union Radio Corp. From 1947 to 1950 he was associated with Telvel Laboratories as production manager.

Col. Howard W. Serig, until recently vice commander of the Air Force Cambridge Research Center, has been made director of a research division group of the Research Division of New York University's College of Engineering which furnishes staff sup-

PERSONAL

(*Continued from page* 167)

port to the Panel on Electron Tubes of the Department of Defense. From 1948 to 1952, Col. Serig was Air Force secretary, Committee on Electronics, Research and Development Board.

Ned J. Marandino has been made manager of the new television set plant in Batavia, N. Y. that is now being

Ned J. Marandino

constructed by Sylvania Electric Products Inc. Mr. Marandino joined Sylvania's radio and television division in Buffalo in 1950 as superintendent of test and inspection.

Jerry B. Minter, vice president of Measurements Corp., Boonton, N. J., and president of Components Corp., Denville, N. J. has been elected president of the Audio Engineering Society. He succeeds **F. Sumner Hall** who has become a governor of the society.

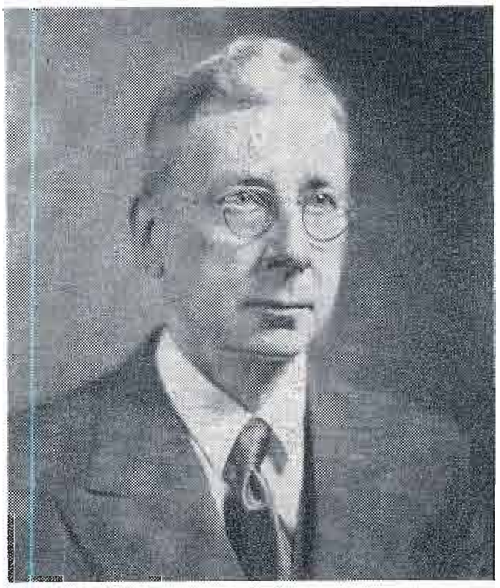
Henri G. Busignies, technical director of the Federal Telecommunication Laboratories, division of IT&T at Nutley, N. J., has been appointed vice-president and member of the management advisory board. Mr. Busignies has been associated with IT&T for nearly a quarter of a century. He joined Federal in 1941 and advanced from senior engineer to technical director during the eight ensuing years. Mr. Busignies is known chiefly as the inventor of the first automatic direction finder for aircraft, now standard equipment on all large commercial and military airplanes.

Elwood W. Schafer, former vice-president of National Union Radio Corp., has been named assistant to **Charles F. Stromeyer**, vice-president in charge of manufacturing and engineering at CBS-Hytron. Mr. Schafer will assist in planning the company's expansion of its TV tube manufacturing facilities, and operate a color tube pilot plant.

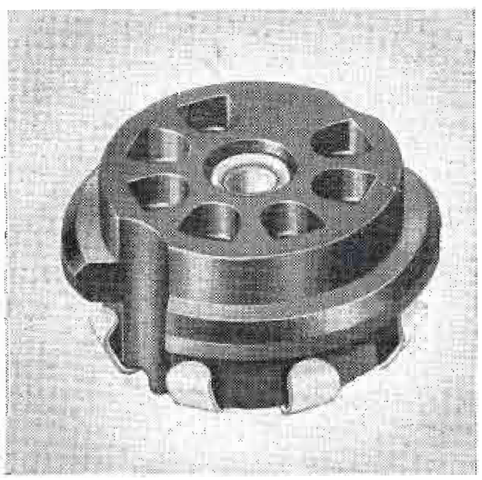
Raymond J. Clancy, Lester F. Clawson, Jr., Bob N. Jasberg, James S. Johnson, Joseph M. Lambert, John P. Malbrain, Jacob Munt, Jon H. Myer, Herman E. Thomason, and **Eden F. Wright** have joined the technical staff of Hughes Research and Development Laboratories, Culver City, Calif.

Fred T. Schick has been named chief mechanical engineer for CBS-Columbia, Inc., TV set manufacturing subsidiary of Columbia Broadcasting System. Formerly, Mr. Schick was head of product design for Allen B. Du Mont Laboratories, Inc., and assistant chief engineer of Emerson Radio Corp.

Dr. Raymond A. Heising retired from the Bell Telephone Laboratories on August 31. Dr. Heising is one of the Bell System radio pioneers. He entered the employ of the Western Electric Company in July, 1914 and immediately began work on high frequency communication. He set up in the laboratory the first carrier on wire system. He developed their first radio transmitter which was tested at Montauk, Long Island in April, 1915, and developed the radio transmitter that was installed at the Arlington, Virginia Naval Antenna (which was borrowed) in 1915 with which transcontinental and transoceanic demonstrations of radio telephony were made that fall. A two-way conversation between New York and San Francisco was demonstrated with radio providing the circuit in one direction from Arlington to San Francisco. One-way speech demonstrations were made to Darien, Canal Zone, to Honolulu, and to Paris. Dr. Heising participated in the research and development connected with the pioneer long wave and short wave transoceanic commercial radio telephone circuits. He transferred to the Patent Department in 1945 and has since been engaged in patent engineering and other patent work. He is planning to continue his activities as an independent consulting engineer and patent agent, with headquarters at 232 Oak Ridge Ave., Summit, N. J.



Dr. Raymond A. Heising



Waveguides for UHF

(Continued from page 83)

Table I compares waveguide to 6⅛ in. coaxial line, and shows the number of years to balance costs. Referring to this figure, for example, for a 1,000 ft. tower and operation on Channel 77, after 1.2 years the extra cost of the waveguide is made up in operating savings, and after that period these savings continue. A similar comparison to 3⅛ in. coaxial line will reveal comparable results.

It will be observed in Table I that, for Channel 49 operation, WR-1150 costs are balanced out in a shorter time than are WR-1500 costs. However, the actual dollar saving in operating costs is greater for WR-1500, as might be expected because of its lower attenuation. For example, for a 1,000 ft. tower the estimated annual operating saving is $2200 for WR-1150, as compared to $4000 for WR-1500.

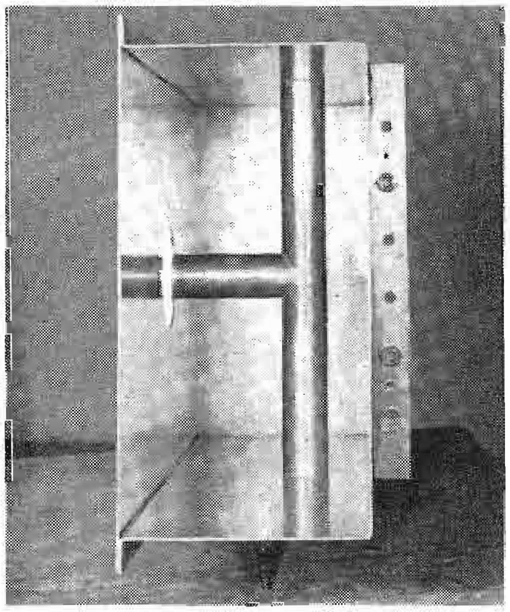
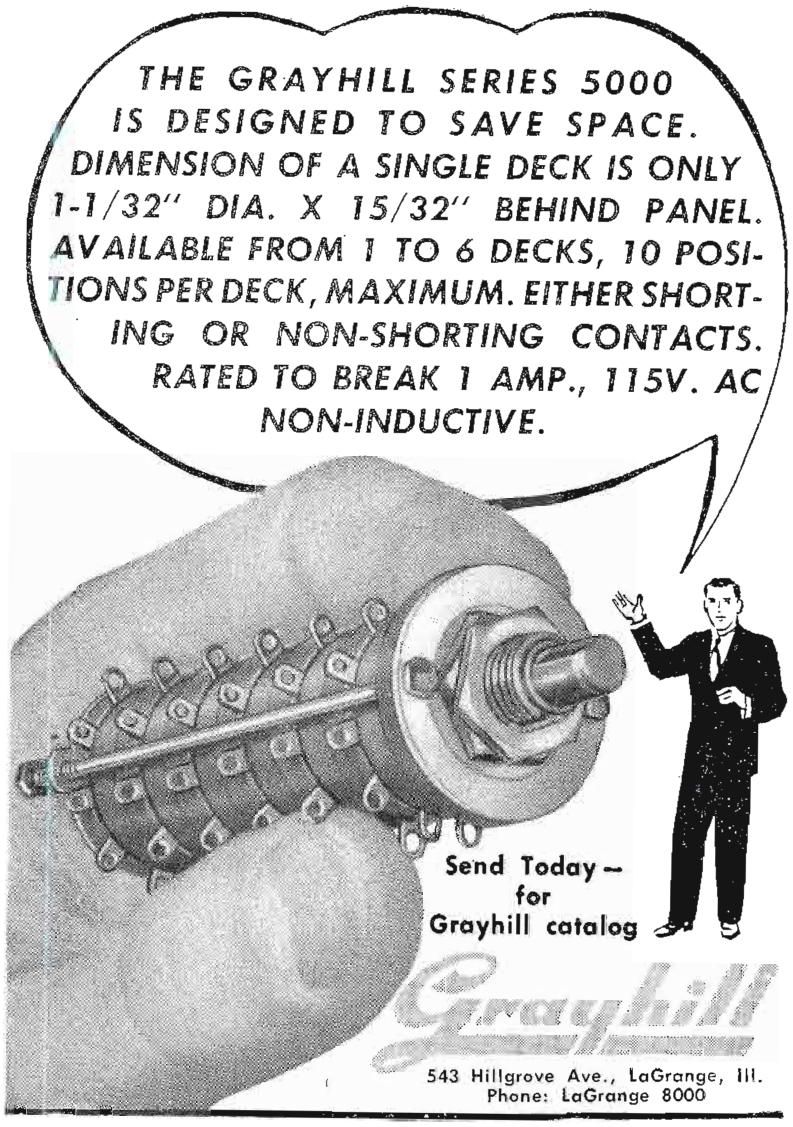


Fig. 5: Mounting hanger attached to waveguide seam for supporting the waveguide on a tower

Many approximate cost assumptions were made in preparing this table, and these assumptions will be far from right in individual cases. However, the results indicate a definite economic advantage in favor of waveguide.

One UHF-TV station has been on the air for sveeral months using waveguide. WHUM in Reading, Pennsylvania, is operating on Channel 61, 752-758 MC, using a 1036 ft. tower. WR-1500 waveguide is installed on this tower. The performance of the waveguide is satisfactory and the VSWR which includes approximately 1090 ft. of waveguide and several fittings is less than 1.2, as measured with a dummy load with a VSWR of 1.05. (VSWR information provided by the General Electric Company.)



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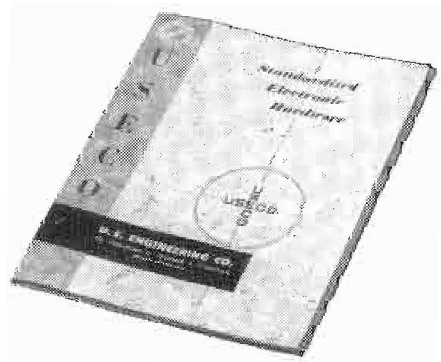

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Directional Couplers

(*Continued from page 97*)

and permits the formulation of a more general scattering matrix for a directional coupler. Experimental verification of the above theory is presented in Fig. 7 for the case where Z_{33}' only is mismatched.

The new scattering matrix which was derived is shown in Fig. 8a. This matrix includes the mismatch conditions as stated above. The various elements of the matrix are scattering coefficients and are a measure of the amplitude of the wave scattered into one pair of terminals by an incident wave of unit amplitude on another pair of terminals. If we limit ourselves to the usual definition of a directional coupler and consider matched lines only, it can readily be shown that the scattering matrix of Fig. 8a reduces to the scattering matrix of Fig. 8b, which is usually regarded as the standard form for a directional coupler.

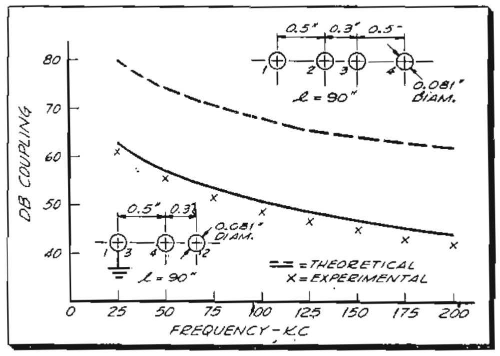

Fig. 11: Three-wire coupling vs frequency

Up to now we have primarily been concerned with coupling sections which were small compared to a wave length. In order to be more general it is desirable to include the case where the coupling section is greater than a fractional wavelength. It has already been stated that a single wave traveling in the reverse direction on the secondary line results, at any point of coupling, along two matched transmission lines. This is true for every point of coupling. However, the manner in which these individual waves add together at the receiving point on the secondary transmission line will be a function of their relative phases. For long coupling lengths, phase shifts will occur. Using this concept, an analytical expression for the coupling (expressed in decibels) as a function of length can be derived. The directivity of such a matched system will remain infinite even though the phase may vary from point to

(*Continued on page 175*)

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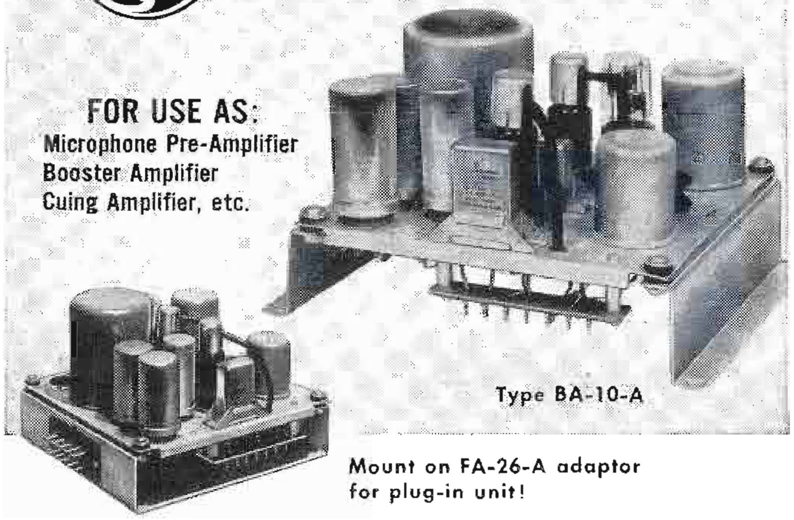

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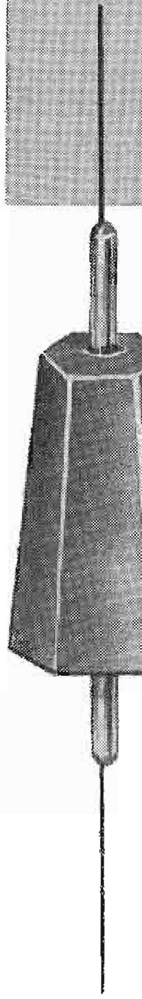

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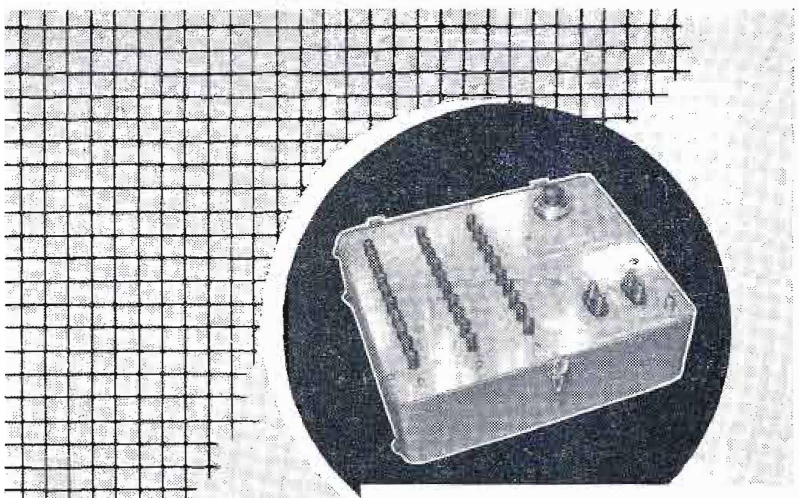

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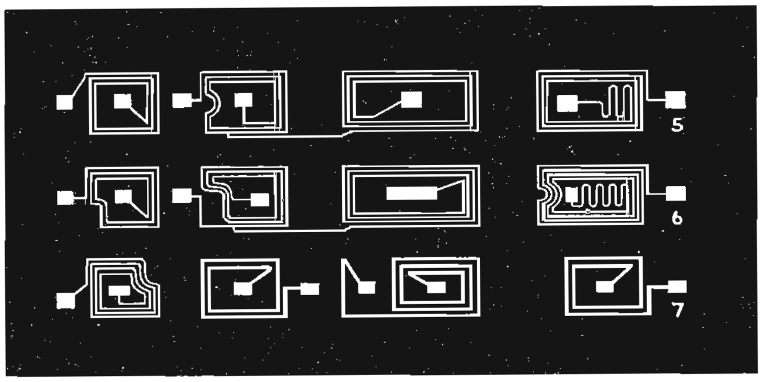

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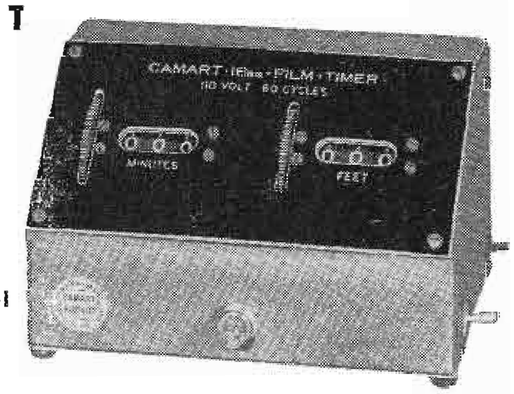

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point, because each point sends energy only in one direction.

Fig. 9 shows the voltage and power variation in the desired direction on the secondary line and includes the analytical expression for the coupled energy to be expected. We may now observe that when β is small the equation in Fig. 9 reduces to the simplified form given earlier in Fig. 3. A result we would naturally expect. A little consideration of Fig. 9 will show the feasibility of reversing the phase of the coupling every quarter of the wavelength. Another possible arrangement which is even more effective in transferring power, can be achieved by introducing 240° phase shifters at 60° phase intervals along the primary line.

Other Directional Systems

By the use of electrical images two one-wire transmission lines with a ground plane can be shown to be equivalent to an open four-wire system. Two different experimental curves of frequency versus amount of coupling with the coupled length as a parameter, are presented as corroborating evidence in Fig. 10.

A three-wire system which represents two transmission lines with a common ground wire can be shown to be equivalent to a four-wire system in which each transmission line is an unsymmetrical transmission line. This is done by imaging the two active wires into the ground wire. A three-wire system can also be shown to be equivalent to a four-wire system in which each transmission line is a symmetrical transmission line. This is done by the use of conformal mapping and is justified only as long as the transmission line propagates the TEM mode. Experimental verification is presented in Fig. 11 and a comparison of the amount of coupling of the three-wire coupler with a comparable four-wire system is given. Because the images are so close to each other in the three-wire system a large increase in coupling was experienced as compared to

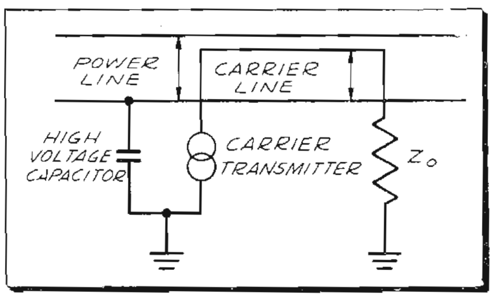

Fig. 12: Directional coupler for power lines

DIRECTIONAL COUPLERS (Continued)

the four-wire system. A method applying this three-wire system to power lines is shown in Fig. 12.

A symmetrical four-wire system with two wires grounded can be shown to be equivalent to a three-wire system and some experimental evidence is shown in Fig. 13, is presented.

A fifth configuration which has a grounded shield surrounding the two active wires is investigated for directional coupling characteristics. Each wire with the shield represents one transmission line. By the method of images, it is possible to image the two active wires into the shield. It can be shown that this problem also can be reduced to that of the three-wire directional coupler, except that, instead of imaging the two active wires into a common ground wire, they are imaged onto the outside of the ground shield. The same mathematics apply in either case. Some typical experimental verification for the shielded two-wire directional coupler is presented in Fig. 14.

One of the most desirable features of all directional couplers of the open-wire transmission-line is their relative insensitivity to variations of frequency. If coupling sections of one quarter wave-length at the center frequency are utilized, then a frequency range of approximately three to one will cause a variation in coupling of only three decibels.

Lumped Circuit Directional Couplers

In addition to the above distributed parameter type directional couplers, it is possible to develop lumped circuit directional couplers

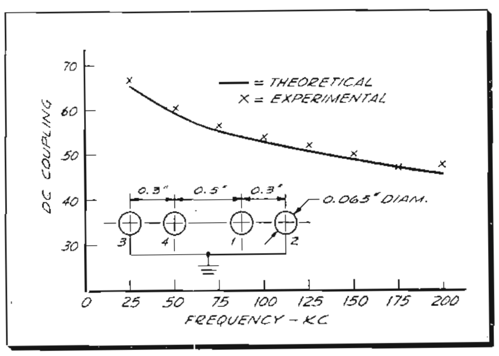

Fig. 13: Coupling-frequency, 2 wires grounded

which embody essentially the same basic principles. The "characteristic equation" previously developed for directional conditions to obtain, was given as

$$M/C_m = Z_{01} Z_{03}.$$

If one considers that the coupling may be done by lumped circuit parameters, that is, M and C_m are lumped values, it is possible to arrive at the configuration of Fig. 15. In this case it is understood that the transmission lines themselves do not couple any energy and it is clear that if the polarity of either-winding of the transformer is reversed that the directional properties reverse. This

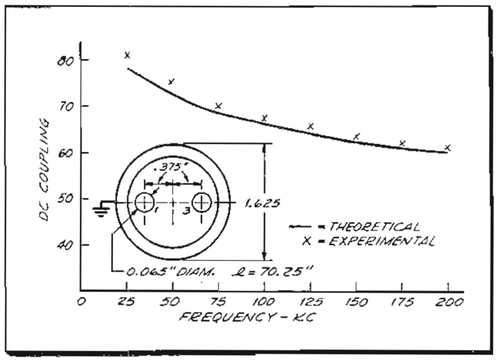

Fig. 14: Shielded line coupling vs frequency

permits either reverse or forward coupling.

Also, one may couple onto the secondary line without any primary line. Fig. 15 still applies, provided line (1, 2) is not a line at all. This configuration shows high directivity and can couple practically all of the energy from the generator onto the secondary line in the desired direction. Directivities greater than 45 db. are couplings of less than —1 db. are easily achievable. Zero db. means all of the energy is coupled over.

If Fig. 15 is modified so that there are in fact no transmission lines but only wires exist, it is still possible to obtain directional coupling. However, in this case the relations, as derived for the transmission line couplers, may be somewhat modified.

Each of the directional couplers developed have certain advantages which are pointed out below:

1. The four-wire system is the most desirable for high-voltage systems where voltage breakdown is a factor.

2. The two-wire system requires the least wire and is, therefore, desirable where economy is a factor.

3. The four-wire system with two wires grounded is most desirable where the wires must be high off the ground and the impedance of each line is desired to be low. This arrangement yields much higher coupling than either of the above systems, but requires two of the wires to be at a common ground potential.

4. The three-wire system is best suited for applications where one wire may be used as a common wire and a high degree of coupling is desired.

5. The shielded two-wire system has practically no noise or other extraneous voltages induced and, hence, is desirable whenever interference is important.

(*Continued on page* 178)

DIRECTIONAL COUPLERS (Continued)

6. The lumped circuit coupler has the highest amount of coupling, requires practically no coupling length and does so with a high directivity. This unit could be contained on a small radio chassis if desired.

It was the purpose of this paper to present an analysis on directional couplers at the lower radio frequencies. Five different types of transmission line systems have been shown to possess directional properties. The conditions of mismatch on either transmission line, as well as lengths of coupling greater than a fractional wavelength, have been taken into account. In addition, lumped circuit directional couplers have been developed as a consequence of the general transmission line theory. All of the couplers should have application in the radio field and the extension of the art of directional coupling to the lower radio frequencies should prove of great value. It is hoped that this paper will stimulate interest in this aspect of communications.

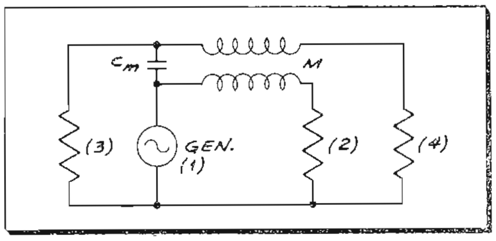

Fig. 15: Lumped circuit directional coupler

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