RADIO

APRIL, 1945

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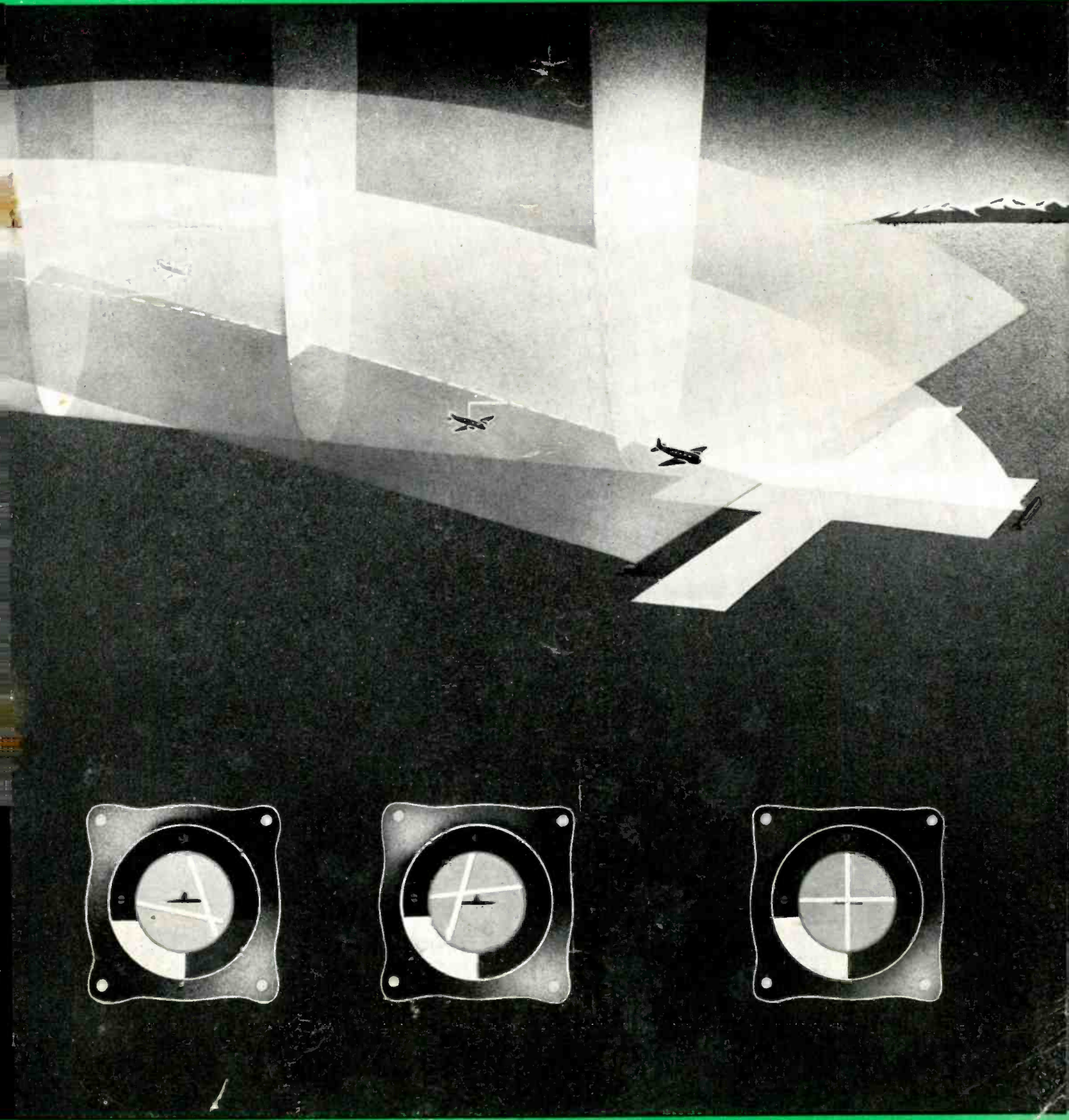

The Journal for Radio & Electronic Engineers

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TRANSFORMERS

RADIO

Published by RADIO MAGAZINES, INC.

John H. Potts.............Editor
Sanford R. Cowan........Publisher

APRIL 1945 Vol. 29, No. 4

CONTENTS

COVER

CAA landing system. This illustration shows relative positions of signals used in the system. The localizer beam emanating at the end of the runway, the glide path beam from the side of the runway, and the inner middle and outer markers. The cross pointers indicate the position of the plane relative to glide path and localizer beams.

The CAA will have over 100 of the systems operating before the end of 1945

ARTICLES

MISCELLANEOUS

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Sanford R. Cowan..........Sec'y-Treas.
Charles H. Farrell.........Adv. Manager
Ann Limberg...........Adv. Production
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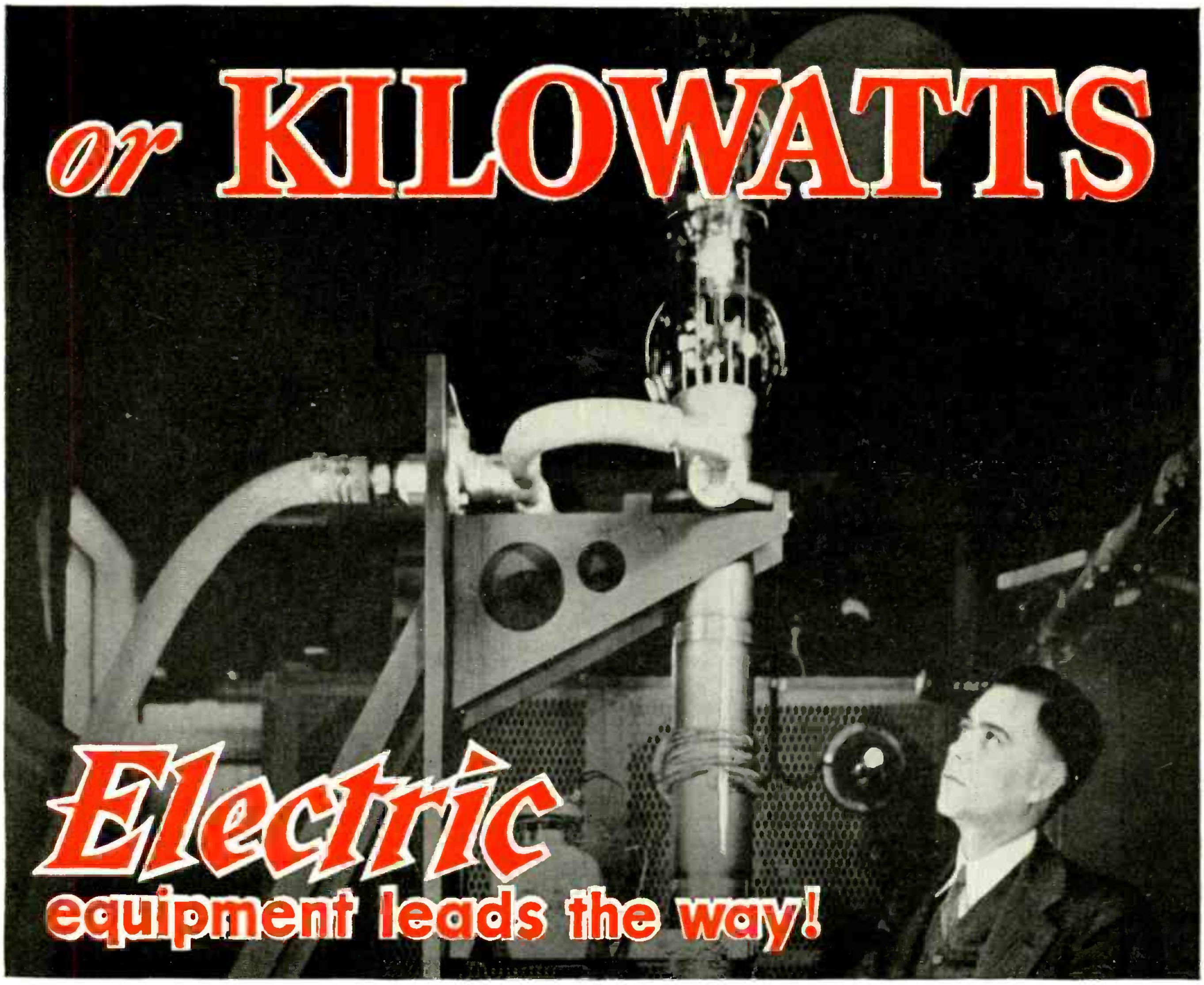

types of tubes have been introduced by Western Electric and Bell Telephone Laboratories for war services. These new tubes — and the techniques used in developing and manufacturing them — will find many important uses in communications at the war's end.

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Transients

CUT-BACK PROSPECTS

★ Recently William L. Batt, Vice Chairman of the War Production Board, issued a statement which reflects the present ideas of the WPB with respect to the degree of reconversion to be expected after V-E day. He says, in part:

"Our communications, radio and electronic equipment represent a combined cost of $9,405,000,000.

"My experience with our thinking and talking about reconversion early last Fall leaves me with the feeling, much as I regret to say so, that this is no time to be even talking about reconversion, and I'm convinced that we've got to be more cautious in talking about it in the future.

"Such thinking and planning—and I wish this were not so—seems immediately to reflect itself in less energetic war production. Most of us believed for a long time that we could carry forward two jobs at once —think reconversion while producing all-out. We tried and we couldn't do it. I don't want to sound too much like a pessimist. I am just speaking to you with deepest sincerity from the basis of actual experience.

"I am a little proud in my own mind that I never set a date for the end of the German War. I am not going to set a date for the end of the Japanese war. There are three things about the Japanese that must not be overlooked: (a) the Japanese land army is today numerically just about as large as the German Army was at its peak; (b) the largest part of the Japanese army and what is really their "first team" army is still up north in Manchuria; (c) they are still a desperately dangerous enemy with completely unknown powers of continued resistance.

"I can tell you that our military men may not use much of the equipment they have employed in Europe against the Japanese. Secretary Stimson says they will use what they can . . . Weapons designed for the fairly good highways and rail transportation of Europe are not necessarily adapted to the primitive conditions of the Far East.

"Further than that, just the mechanical job of cleaning up, repairing and packing much of the equipment which we have been using in Europe, so that it can be shipped to the Pacific, is an appalling job and to a very considerable degree simply not practicable. Anyone who has been through the business of assembling material and spares at the point of production for use abroad will understand that situation only too well.

"I think the inevitable result must therefore be that as we move to the Orient from Europe, our Army and Air Force will have to be pretty completely re-equipped. This is another part of the big job ahead of us.

"I remember last summer Donald Nelson, Charlie Wilson, Cap Krug, and myself were thinking in terms of a 40 per cent reconversion at the end of the German War. Today, whenever we think of those cut-back figures at all—which I can assure you is very rarely—our most optimistic figure for the post V-E day reconversion is 20 per cent, and certainly I don't see that ahead for many months."

In line with the above, a good many manufacturers have learned through bitter experience that thorough tropicalization of radio-electronic equipment is necessary for apparatus destined for service in the tropics. The wide acceptance of foreign radios in South American and Oriental countries is due, in part, to the fact that foreign manufacturers found this out before the war and acted accordingly. For many American makes, such countries proved to be a radio serviceman's paradise and a radio dealer's headache.

We are going to need foreign markets to absorb our surplus production, and it is not too early to give earnest consideration to methods of successful economic penetration of such markets. In the past, many radio manufacturers have worked under the disadvantage of not only ignorance of the technical requirements, but also of merchandising methods which meet foreign competition. Long-term credits, financed by governmental subsidies, have smoothed the way for foreigners in building up a demand for their equipment. Our smaller manufacturers are going to need this same sort of assistance after the war and, most certainly, the larger ones are not going to object to any schemes which will relieve them of the financial burden of carrying long-term paper of often somewhat questionable merit, as viewed by our credit standards.

We need further to concern ourselves with proper styling of cabinets to meet popular tastes in foreign countries. One of the things that our auto manufacturers learned through experience is that residents of tropical countries like bright colors, and more ornate decorations. There should be a good opportunity to use to our advantage multi-colored plastics in cabinet design, more brilliant and colorful dials, more extreme designs insofar as lines are concerned.

Reconversion is going to be simpler and faster for us than for other countries. But let's not repeat our former mistakes this time. The world depends on us.

J. H. P.

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TECHNICANA

TONE CONTROL

★ Tone control devices do not merely reduce top or bottom frequency response, but increase bass or treble frequencies with respect to the middle of the band.

Mr. G. N. Patchett, in an article entitled "Tone Control Circuits", Part 1, appearing in the March 1945 issue of *Wireless World,* opens a discussion of tone control on the basis of this principle.

The use of an interstage tone control is illustrated in *Fig. 1.* The impedances

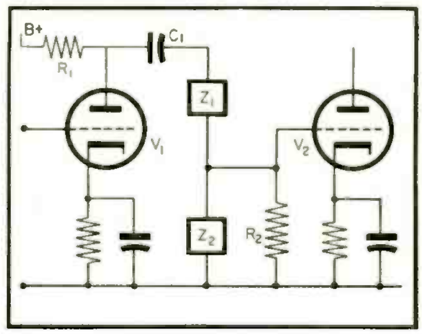


Figure 1

Z_1 and Z_2 form the frequency discriminating circuit. The values of Z_1 and Z_2 should be as high as possible, to minimize distortion, but R_2 must be much greater than Z_2. Also, C_1 must be large enough so that its low-frequency reactance is small compared to $Z_1 + Z_2$.

For increasing bass response the circuit of *Fig. 2* is employed. In the

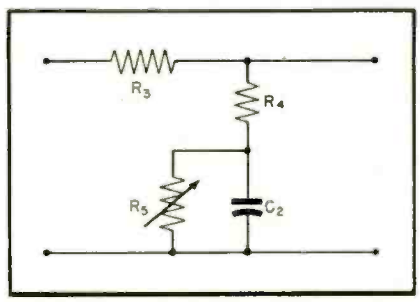
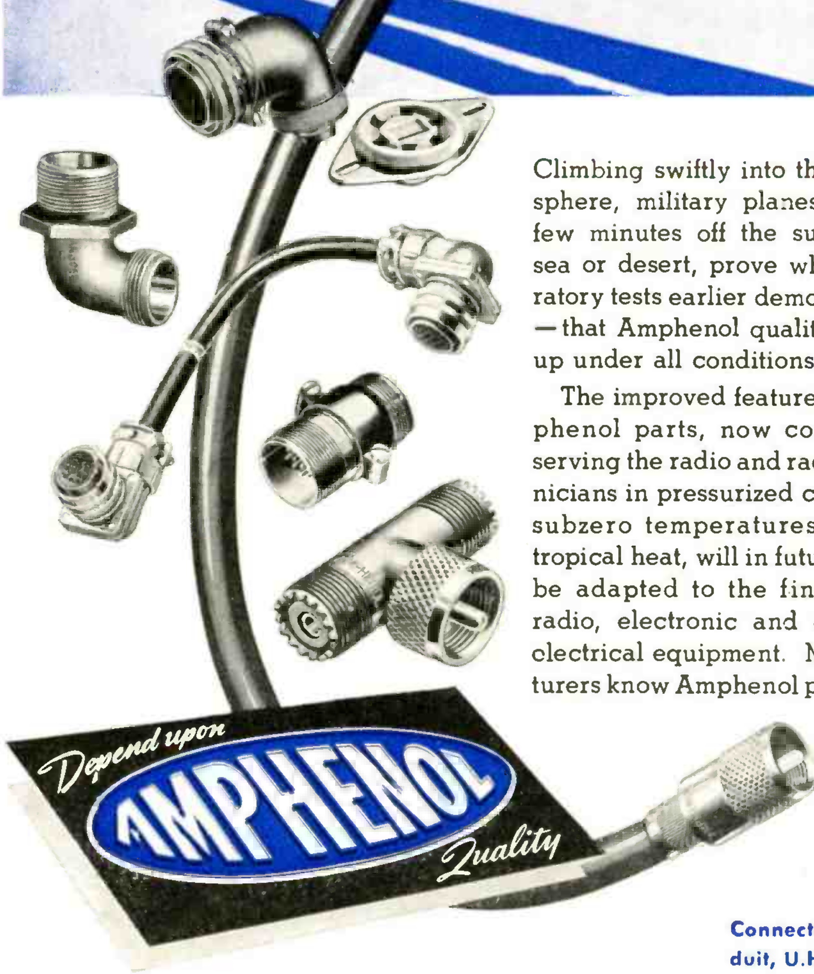


Figure 2

simplest case, R_5 is omitted. It is not practical, however, to vary R_4, as this would produce a large change in volume. It is also impractical to vary C_2 continuously with the values required (.02 to 0.2μf).

When variable resistor R_5 is employed the volume remains substantially



Climbing swiftly into the stratosphere, military planes only a few minutes off the surface of sea or desert, prove what laboratory tests earlier demonstrated —that Amphenol quality stands up under all conditions.

The improved features of Amphenol parts, now constantly serving the radio and radar technicians in pressurized cabins, at subzero temperatures and in tropical heat, will in future years be adapted to the finest new radio, electronic and exacting electrical equipment. Manufacturers know Amphenol products; have used and tried them to the limit—and appreciate their possibilities.

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constant, but the shape of the frequency response curve differs for different settings of R_5.

The author recommends the elimination of R_4 in *Fig. 2,* and using a high resistance value of R_5. When, to the output, a voltage independent of frequency is added, the response curve of *Fig. 3* is obtained. The tone control

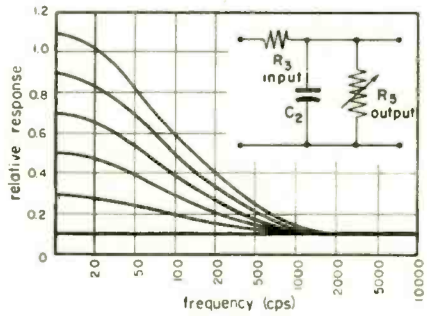

Figure 3

gives a continuous variation in the relative magnitude of the bass frequencies with respect to the middle frequency, without altering the shape of the curves.

For top frequency control the capacitor of *Fig. 2* could be replaced with a variable inductor if this were practical. Instead the circuit of *Fig. 4* is em-

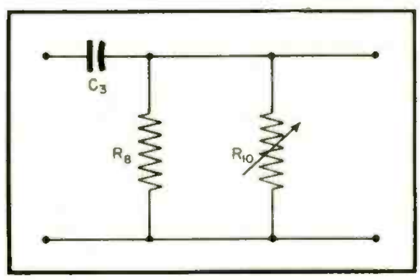

Figure 4

ployed. When a voltage independent of frequency is added to the output of R_{10}, a response characteristic which is a mirror image of *Fig. 3* is obtained.

Typical values for *Fig. 3* are R_3 = 50,000 ohms and C_2 = 0.05 µf. For *Fig. 4*, C_3 = .0005 µf and R_8 = 50,000 ohms are typical values. The constant voltage to be added to the output equals 1/10 of the maximum filter voltage output. The author will continue this discussion in a later issue.

CATHODE BIAS CAPACITORS

★ It is usually desirable to omit a bypass capacitor across the cathode re-

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To meet the need for a light-weight, high-capacity, high-voltage tank condenser for transmitter applications, Johnson engineers developed a new type of condenser. The unit illustrated has a capacity of 1200 mmf. at a peak voltage of 40,000 volts at 2 megacycles. Nearly any combination of capacity and voltage ratings may be had. The capacity may be varied in the field by removing plates or altering spacing.

The plates are made of fabricated sheet steel, heavily copper plated and enamelled. Rounded edges increase the breakdown voltages. Vertical tie rods of copper tubing furnish good conductivity between plates. Plates are secured to the upright supports with aluminum castings.

A protective gap is incorporated in the condenser to protect the plates from damage in case of excessive voltages or surges. The mounting base is welded channel iron, which forms a strong support. A very convenient mounting for the tank inductance is formed by the two cross beams at the top of the condenser.

This condenser will find wide application in high power equipment because of its compact and efficient construction.

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sistor in a push-pull amplifier stage The one exception to this rule is with true class AB amplification wherein distortion is fairly high.

This conclusion is reached by Mr. W. T. Cocking in an analysis of this subject, entitled "Cathode Bias in Push-Pull Stages", which appears in the March 1945 issue of *Wireless World*.

For the case when the two tubes are matched, and have linear characteristics, mismatch of the input voltages may occur, in a circuit as shown in *Fig. 5*.

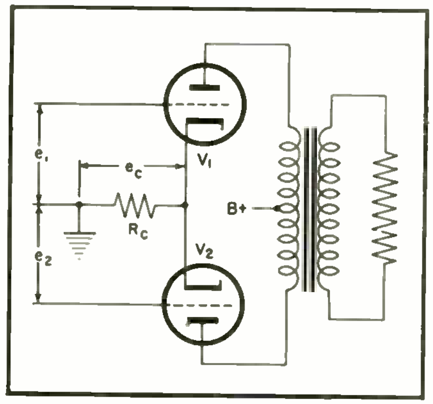


Figure 5

When e_1 is slightly greater than e_2, a voltage e_c is developed across R_c. This voltage is in phase with e_1 and opposite in phase to e_2. The grid bias on V_1 is $e_1 - e_2$, and the grid bias on e_2 is $e_1 + e_2$. If a by-pass capacitor were used, no voltage would be developed across R_c and the anode currents would be further out of balance than if no capacitor were used.

If the input voltages are equal but the amplification factors or plate resistances are slightly different, the same conclusion is obtained. For example, with plate resistances of 1000 ohms and 800 ohms, and R_c = 500 ohms, the anode a-c current unbalance of 2½% would be increased to 25% by use of a sufficiently large by-pass capacitor.

Fig. 6 illustrates a resistance-coupled stage. Any inequality between the input voltages, or the tubes, is again counteracted by R_c, which, in fact, produces a feed-back tending to equalize the variations between the two halves of the amplifier. In this case, R_1 and R_2 must be closely matched, or else R_c will actually increase the voltage unbalance in the output.

With balanced plate resistors, and R_{P1} = 20,000 ohms as against R_{P2} = 15,000 ohms, the output voltage unbalance of 3% is increased to 7½%

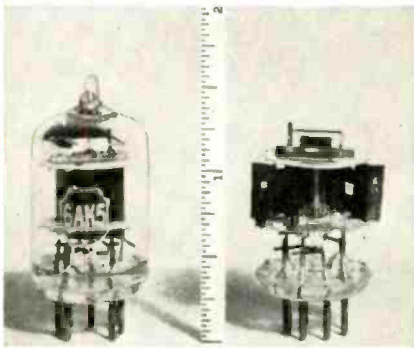
SYLVANIA NEWS

ELECTRONIC EQUIPMENT EDITION

APRIL — *Published in the Interests of Better Sight and Sound* — 1945

Miniature Pentode Designed for Use In UHF Circuits

Tube Type 6AK5, a new addition to Sylvania Electric's line, is a miniature sharp cut-off pentode in the short bulb, and is especially suitable for use in ultra high



frequency equipment. Small size and high efficiency make it useful in portable equipment.

Full technical information may be obtained from Sylvania Electric.

SYLVESTER SURVEY

"Would you say your postwar radio choice would be the large console type or the smaller, table-top model?"

Oscillographic Technique Traces Tube Performance in New Regions

Method Devised by Sylvania Electric Throws New Light on Characteristics

The measurement of tube characteristics in regions where previous test methods were inapplicable has been made possible through the development, by Sylvania Electric, of a new procedure, based on photographing an oscillographic trace.

EARLIER METHODS

Formerly, tube characteristics were taken by a point-by-point method. This was extremely slow, and had the still greater disadvantage that it could be used only in those parts of the characteristics where the tube would not be damaged by continuous operation. In many recent applications, characteristics must be known in regions where a plate or grid would vaporize if left on for even a second.

PHOTOGRAPHIC RECORDING

The new technique permits taking of characteristics in these regions. The oscillographic trace of the characteristics is shown on a special Sylvania 7-inch cathode ray tube, and may be photographed.

Improved tubes and circuits are expected to result from the use of the new method, equipment for which was built in Sylvania Electric's Commercial Engineering Laboratory.

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when a cathode by-pass capacitor is used. For this example $\mu = 40$, $R_1 = R_2 = 50{,}000$ ohms, and $R_c = 1{,}000$ ohms.

When R_c is not by-passed, the matching of the load resistors is much more important. Usually the two resistors shoud be matched to within 2%.

Much more important, generally, than input voltage or unbalance between the tubes, is the effect of nonlinearity in the tubes. In general, the use of a by-pass capacitor will eliminate from the output a series of odd harmonics. This odd-harmonic distortion can be considered negligible, however, whenever the second harmonic distortion per tube is less than about 5%. In such cases the capacitor can be eliminated as it improves the balance of the stage in other respects.

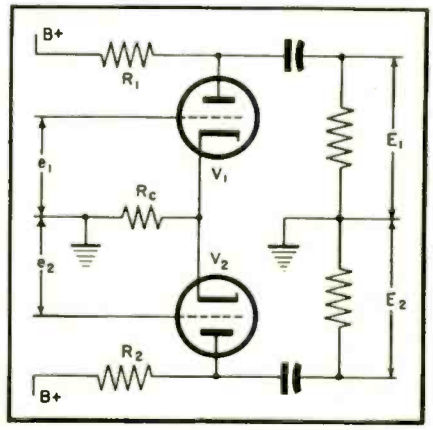

Figure 6

When R_c is not by-passed, and assuming the use of tubes having square-law characteristics, the second harmonics are in phase in the cathode circuit although cancelling out in the output. These second harmonics in turn produce third harmonics in the output, and other odd-harmonics of higher order.

With a true class AB amplifier the distortion per tube is fairly high so that shunt capacitors for the cathode resistors are advised.

In heavy Class AB, and Class B, a fixed grid bias should be used, so that the by-pass capacitor is not necessary.

SHIELDING INDUSTRIAL GENERATORS

Tests conducted by RCA Victor have shown that separate shielding of proper design for electronic power generators, work assemblies, and transmission lines

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will reduce the field strength of radiations which might interfere with home radio reception and other electronic services by a factor of 45,000 to 1.

Results of the recently completed tests, whcih were conducted at a distance of one mile from the generator, were described in a paper presented by G. H. Williams, RCA Victor development engineer, at a meeting of the Philadelphia Section of the American Institute of Electrical Engineers at the Engineers Club.

Advantages of separate shielding, aside from the circumstance that it may sometimes be impossible or inconvenient to house a complete electronic installation in a shielded room, include the fact that the former method is substantially less costly, Mr. Williams pointed out.

Without shielding, he said, the field strength of interference radiations from a dielectric heating installation operating on a frequency of 9 megacycles was found to be 316 microvolts per meter. With a single screen cage over the work load, this factor was reduced to 1.3 microvolts. A further reduction to .007 microvolts was obtained by placing a double screen cage over the applicator and load.

With such an arrangement, Mr. Williams pointed out, the entire value of the shielding would be temporarily nullified every time it was necessary to open a work-access door, unless some special provision were made. Without such provision or the alternative of switching off the power every time a door in the cage was opened, the field strength of radiations at one mile in these tests would have jumped to 316 microvolts and remained there until the door was closed.

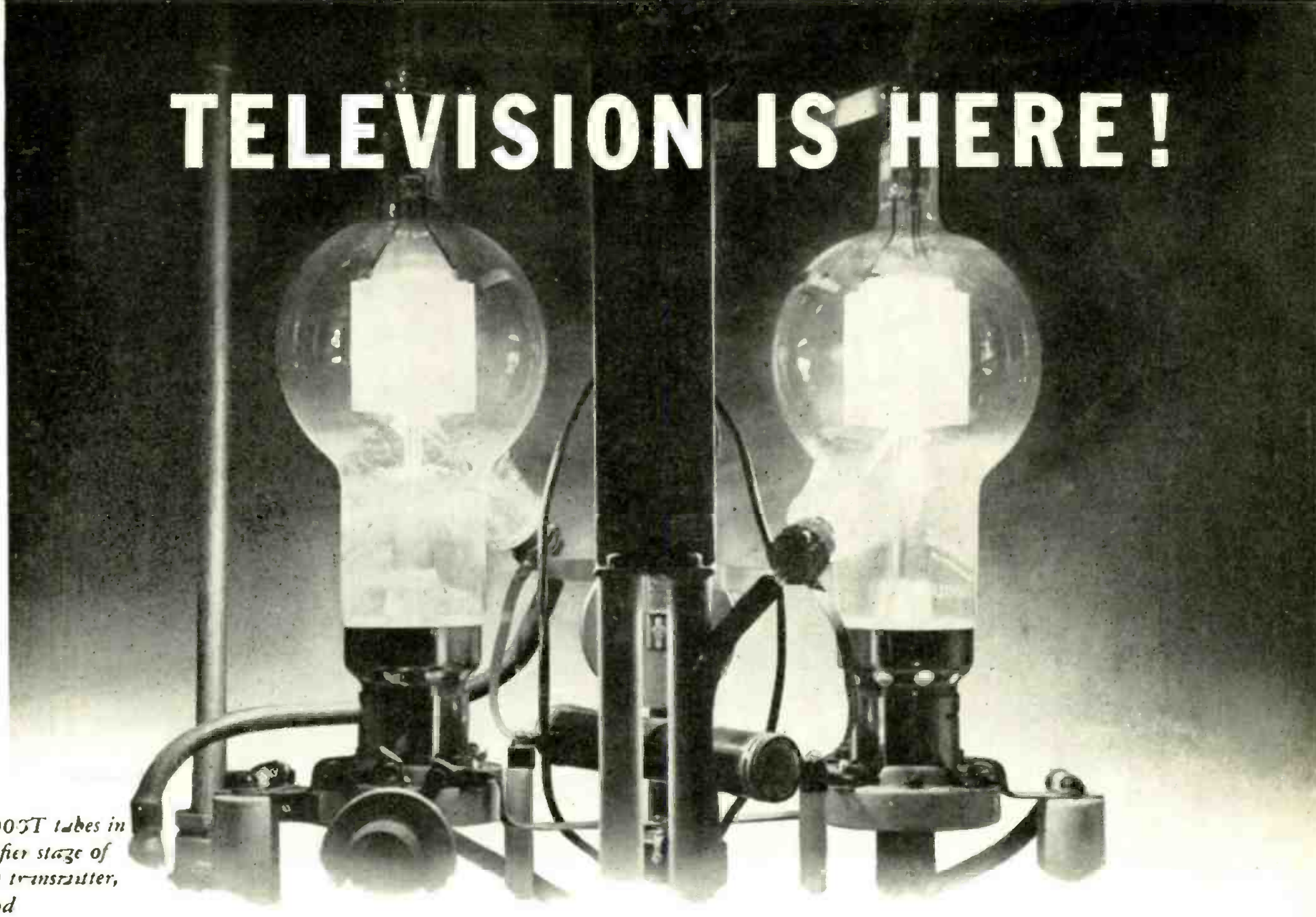
A solution was found for operations in which a conveyor belt could be used to carry work to the applicator assembly, he said, by cuttting an opening in the side of the cage to admit the belt and the work and extending outward the edges of the opening. This measure served to trap the greater part of the radiations which would otherwise escape.

When a slot 1 inch high by 30 inches long was used, with the edges extending 8 inches perpendicular to the cage, the radiation field strength at one mile was only .04 microvolt.

PRINCIPAL LIMITATIONS OF DIELECTRIC HEATING

Carl J. Madsen, Electronics Engineer
Westinghouse Electric and Mfg. Co.
East Pittsburgh, Pa.

With the popularity of high-frequency heating growing by leaps and bounds, it is desirable to stop for a moment now and then to take stock of the state of the art. This can best be done by breaking down the broad view and reviewing only a narrow phase at a time. This paper is concerned with only dielectric heating (heating of materials by a varying electric



Eimac 1000T tubes in an amplifier stage of W6XAO transmitter, Hollywood

At Don Lee Hollywood...Station KTSL using EIMAC TUBES *since* 1938

Julia Lee Wright, noted Home Economics Director of "The Family Circle" magazine being interviewed, and telecast revealing tricks of her trade.

Two young comedians, Robert Sweeny and Hal March, currently on transcontinental radio show, give a preview of their talents for television broadcast over W6XAO.

Write for your copy of Electronic Telesis—a 64 page booklet fully illustrated—covering the fundamentals of Electronics and many of its important applications. In layman's language.

Work on television station W6XAO (Commercial station KTSL) began in November 1930; and thirteen months later, Dec. 23, 1931, it was on the air on the ultra high frequencies, the first present day television to operate on schedule. Today the station occupies elaborate copper sheathed studios which stand 1700 feet above Hollywood with an antenna on a 300-foot tower.

The program log shows almost every type of presentation. Highest in interest and achievement are the remote pick-ups and special event broadcasts made simultaneously or recorded on film for release later. Studio presentations, especially those directed to war activities, have become a duration standard.

Under the direction of Harry R. Lubcke, television station KTSL will be in daily schedule immediately after the war. Mr. Lubcke says: "We have been using Eimac tubes in our television transmitter since about 1938 ... We have found them good and reliable performers...their design is such that a favorable ratio of power output to tube and circuit capacitance is obtained ... we look forward to using new Eimac tubes which may be forthcoming."

Here again is a statement from a leader in the field, which offers clear evidence that Eimac tubes are first choice of leading electronic engineers throughout the world.

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field), and reviews the major limitations that prevent universal application.

In considering these limitations, it must be understood that almost all of them are interlocked, to some degree with each other. Hence, in discussing each individually it is well to remember these interrelations when considering an actual application.

COST—High frequency energy is not a cheap source of heat. In terms of dollars per KWH, it will cost approximately \$0.025 to \$0.04 including direct operating cost, maintenance and amortization.

It becomes economical by virtue of one or more of these factors:

1. It produces a result not possible by other methods of heating.
2. It increases the speed of a process and saves labor and/or overall equipment cost.
3. It produces or confines the heating in the part or point where needed, thus reducing overall power consumption.
4. It is clean and compact.
5. It reduces rejects, or improves the production quality of a product.
6. It is flexible in its application to a variety of operations, processes or products.

These factors are often of sufficient importance to make an application economically attractive.

MATERIAL—Dielectric heating is applicable only to materials normally considered poor conductors of electricity or insulators. When the electrical resistivity of a material drops below 1000 ohm-cm, it is usually possible or necessary to use some technique other than dielectric heating. The state and characteristics of the material have considerable influence on the division point, changing it as much as 10 to 1.

A convenient formula for calculating the heating in dielectric materials is given by:

$$W = \frac{1.41\, A\, f\, E^2\, e'' \times 10^{-12}}{d}$$

where W = rate of heating in watts
A = area of electrode in square inches
d = thickness of material in inches
f = frequency in cycles per second
E = voltage RMS
e'' = loss factor of material = $e' \tan\delta$

The following paragraphs discuss briefly each of these factors.

Dimensions—The dimensions of the piece of dielectric material are important in that they may influence an application as to frequency, rate of production or electrode design.

In general, dielectric heating becomes attractive when the thickness of the material is sufficient to make it difficult to heat the material throughout by conventional means. In terms of inches, this will

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[*Continued from page 18*]

vary with the thermal conductivity of the material.

The thickness of the material must be reasonably uniform if uniform heating is desired. If the work is of such shape, (for example, wedge shaped), that two pieces of material can be placed in complementary positions and the resultant thickness be uniform, the material will heat evenly. Special technique in electrode design and arrangement may sometimes be used when dealing with irregular thickness materials. The relation of thickness and voltage will be discussed under voltage.

The area of material to be heated will limit the frequency which may be used, in two ways.

The capacitive reactance of a large area may become sufficiently low as to make tuning of the load extremely difficult if not impossible. The currents involved may also reach magnitudes difficult to handle.

The length of the load may be such as to produce standing waves. This will be discussed further under frequency limitations.

Sometimes it is possible to scan the material thus reducing the electrode area to a value which permits convenient adjustments and frequencies sufficiently high to produce desired rate of heating.

Occasional applications are encountered where a particular area can be heated if the material is stacked, increasing the thickness dimension and thereby reducing the capacity of the load.

Frequency—In general (since the amount of energy introduced into the material is proportional to frequency) the desire is to use as high a frequency as possible. A compromise is usually necessary however, due to one or more limitations.

The effect of large area and low capacitive reactance was discussed previously.

The length of the material may be such as to produce uneven heating due to standing wave effect. The higher the frequency used, the greater the probability of unequal voltage distribution over a given length or area. If the longest dimension of the electrodes is a small fraction of a wave length, or if the material is scanned, this effect is minimized. Ordinarily if the longest distance from the point of connection to the edge or corner of the high voltage electrode is less than 1/16th wave length, very little trouble will be experienced. Heating will be sufficiently uniform to produce a variation of less than 20 per cent over the area involved. In some processes, this may be intolerable, restricting the maximum frequency (or maximum dimensions of the work) to a still lower value.

The *maximum* frequency which can be used without exceeding the above variation in heating can be determined from the formula:

$$f = \frac{62.5}{t\sqrt{e'}}$$

where f = frequency in megacycles
t = maximum distance from point of connection to edge or corner of high voltage electrode in feet.
e' = dielectric constant of material (specific inductive capacity)

Another limitation occasionally encountered is that of generator design for high power at high frequencies. From a practical viewpoint at the moment it appears undesirable to use frequencies above 20 megacycles when powers above about 20 KW are involved.

Voltage—The power input to the material is proportional to the voltage squared. Hence, if the voltage is increased sufficiently, considerable power can be supplied to the work at relatively low frequencies. Two factors limit the voltage which may be applied.

The total voltage between electrodes should be kept under 15,000 volts. It is not impossible to use voltages above this value, but the additional precautions necessary to avoid corona and arc-overs are often more expensive than some other compromise of the engineering factors.

The voltage gradient, that is, the voltage per inch, permissible across the material may be a limiting factor. The radio frequency voltage which will puncture a given dielectric material is generally much lower than the 60-cycle voltage which a material will stand. It appears desirable to keep the voltage gradient below 2000 volts per inch in porous materials and less than 5000 volts per inch on less porous.

Another type of voltage limitation may be reached in some applications where it is impossible to have the electrodes in contact with the material. This gives rise to a condition in which the space between the electrodes is occupied by two materials of widely different dielectric materials. The potential distribution in this case may be such as to cause a breakdown of the surrounding medium (usually air).

Loss Factor—This is a term commonly used to express the degree to which materials will absorb energy by dielectric heating technique. It is easily measured by means of proper equipment. Referring to equation (1), it is obvious that as the loss factor approaches zero, it becomes increasingly difficult to transfer power into the material. A practical lower limit in the loss factor, of materials which can be heated effectively, appears to be between 0.005 and 0.01. Pure polystyrene, quartz and certain other loss materials have loss factors considerably below this value and are exceedingly difficult to heat by dielectric methods.

The upper limit probably blends into the range where the material becomes sufficiently conductive as to respond to inductive fields, although some skin effect will probably be noted before this limit is reached.

ELECTRODES—A whole treatise could be written on electrode design. One point I wish to cover in this discussion is the fact that heat is not generated in the electrodes to any appreciable degree by the dielectric heating process. The electrodes may be heated by heat transfer from the dielectric material being proc-

TECHNICANA

[*Continued from page 20*]

essed. Often this is undesirable due to the temperature reduction of the adjacent material and may become a limiting factor in some processes. Various simple methods are in common use to minimize this effect.

SUMMARY—Dielectric heating is a very useful tool in industry, one which is finding new applications every day. However, as with any tool, there are certain limitations which prevent its promiscuous application to all types of problems. By realizing these limitations, and the series of compromises often necessary, a careful analysis will permit the average electrical engineer to apply it intelligently to work which it can do well.

STANDARD FREQUENCY

This service comprises the broadcasting of standard frequencies and standard time intervals from the Bureau's radio station WWV near Washington, D. C. Starting in Feb. 1945, the service has been slightly extended by broadcasting 15 magacycles at night as well as in the daytime.

The service is continuous at all times day and night, from 10-kilowatt radio transmitters except on 2500 kilocycles per second where 1 kilowatt is used. The services include: (1) standard radio frequencies, (2) standard time intervals accurately synchronized with basic time signals, (3) standard oudio frequencies, (4) standard musical pitch, 440 cycles per second, corresponding to A above middle C.

The standard frequency broadcast service makes widely available the national standard of frequency, which is of value in scientific and other measurements requiring an accurate frequency. Any desired frequency may be measured in terms of the standard frequencies. This may be done by the aid of harmonics and beats, with one or more auxiliary oscillators.

Four radio carrier frequencies are used; three are on the air at all times, to insure reliable coverage of the United States and other parts of the world. The radio frequencies are:

2.5 megacycles (=2500 kilocycles=2,500,000 cycles) per second, broadcast from 7:00 P.M. to 9:00 A.M., EWT (2300 to 1300 GMT).

5 megacycles (=5000 kilocycles=5,000,000 cycles) per second, broadcast continuously day and night.

10 megacycles (=10,000 kilocycles=10,000,000 cycles) per second, broadcast continuously day and night.

15 megacycles (=15,000 kilocycles=15,000,000 cycles) per second, broadcast continuously day and night.

Two standard audio frequencies, 440 cycles per second and 4000 cycles per second, are broadcast on the radio carrier frequencies. Both are broadcast continuously on 10 and 15 magacycles. Both are on the 5 megacycles in the daytime, but only the 440 is on the 5 megacycles from 7:00 P.M. to 7:00 A.M., EWT. Only the 440 is on the 2.5 megacycles.

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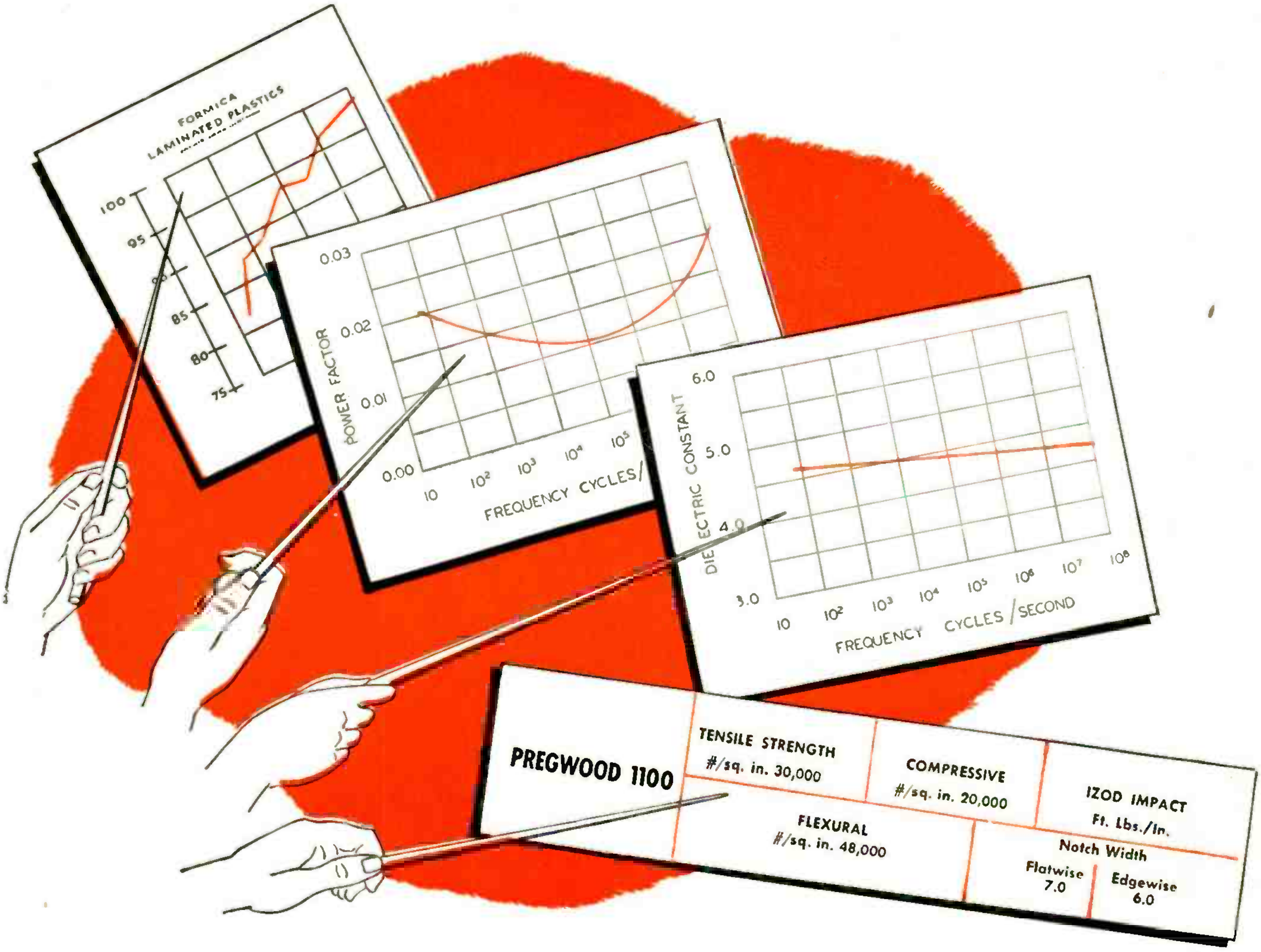

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Parallel Wire TRANSMISSION LINES

ARTHUR C. GARDNER

This article clarifies a subject which has received little attention in textbooks

When it is desired to transmit electrical energy from a source to a load, no problem exists if the distance is small enough. It is only necessary to bridge the gap with a pair of conductors which are of sufficient size and which are adequately insulated and the desired transfer will take place with good efficiency if only the source and load impedances are reasonably well matched. On the other hand, if the separation between the source and load is large, the problem is different. In that case it is necessary to pay attention to the properties of the connecting wires. The connection is then made by a transmission line.

The question of how large is large or when does a connection become a transmission line is one that must be answered in terms of wave length. With direct current a wire of any length can be judged adequate to transmit power on the basis of its size and insulation alone. At audio, broadcast, and even conventional short wave frequencies the situation for wire lengths of a few inches or a few feet is not much different. Shielding may be necessary, and in certain circumstances lead capacitances may be important, but generally speaking the radio engineer is conventionally not much concerned with transmission lines except in the design of the feed to the antenna. This is true because his connections are always shorter than a quarter of a wave length. It is not true when he starts to deal with ultra high frequencies and microwaves. When ten-centimeter waves are utilized a connection needs to be less than an inch long before it becomes a transmission line. A radio engineer who wishes to work with the extremely high frequencies which have become common in the last two or three years must learn much which has previously been utilized chiefly by telephone engineers who, in their long lines, have dealt with distances which are appreciable in comparison to the wave lengths they have had to transmit.

The characteristics of a transmission line which is made up of two parallel wires are well understood. When used either at audio frequencies or high radio frequencies, its properties have been so thoroughly studied that everything about its action can be predicted whether it is used to transmit intelligence, as in a telephone circuit, or whether it is used as a tank circuit which can be made to resonate at ultra-high frequencies.

When the length of a parallel wire line is of the same order of magnitude as the wave length of the alternating current which is to be carried, the wires are frequently referred to as Lecher wires. It was in a study of the now classical Lecher wires that the action of traveling electrical waves first became well understood. It was from such knowledge that engineers were able to proceed to the production of hollow pipe wave guides and resonant cavities which are currently proving to be so very useful in the handling of the really high frequency part of the radio spectrum.

It is because of this recent growth of interest in the ideas of analysis which originally sprung from a study of parallel wire transmission lines, that it now seems worth while to look back over this well established history and see if the problems there cannot be stated and resolved in a physical and coherent manner more useful for people initially studying microwave phenomena without an extensive background of knowledge of communication engineering as it is practiced at lower frequencies. This, plus the fact that a cursory examination of available textbooks shows none which treat parallel lines as a subject in themselves, has been the reason for writing the present article. Textbooks on transmission lines are more apt to plunge directly into the more general case and dismiss the subject of parallel wires with a short paragraph and a few illustrative problems. They contain all the information but in a form which, because of its generality, is mathematical rather than physical and in some cases rather hard to grasp.

A discussion of parallel wire transmission lines naturally divides itself into three parts. The first has to do with action at low enough frequencies so that radiation may be dismissed with a statement concerning the way in which the fields cancel; the second deals with operation at high and ultra high frequencies where radiation is important but still may be considered small if proper precautions are taken; the third is a discussion of the failure of such a simple line when an attempt is made to utilize it for true microwave frequencies. The first part of the discussion is illustrated by long telephone lines and many antenna feeds; the second part is in the domain of the Lecher wire; the third part indicates the inescapable difficulties which can be overcome only by the use of coaxial lines and hollow pipe wave guides.

The Long Line Problem

It is the distributed nature of the parameters which describe long electrical lines that are most important. In a lumped-constant circuit we can say

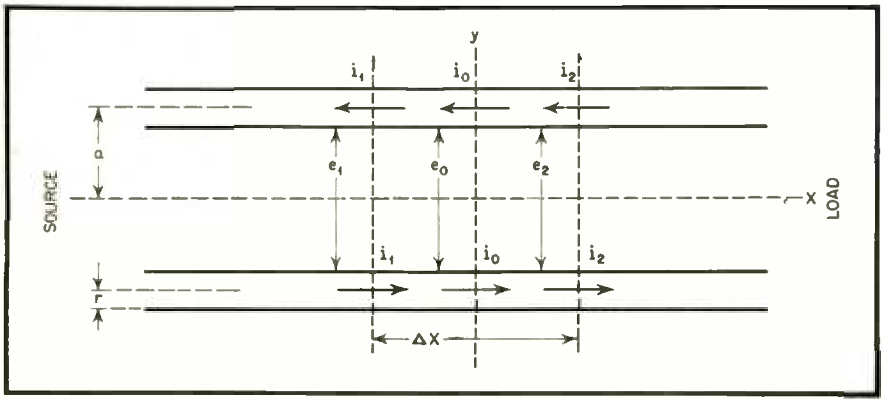


Fig. 1. Voltages and currents as they exist in a short length of a parallel wire transmission line

that a certain inductance or capacitance is inserted at a given point, with transmission lines we cannot. It is not particularly helpful to know the inductance generated by a loop of wire formed by two long parallel wires spaced 6 inches apart and short circuited at the far end nor is it of direct value to know the capacitance that these two wires represent when they are used as opposite plates of a condenser. Such measurements cannot help us analyze the operation of a transmission line because we do not know how to draw and solve an equivalent lumped-constant circuit into which we could insert the measured values. Instead we must return to first principles, ask what it is we want to know, and seek a way of getting the solution that is quite different from our usual way of solving problems which concern coils, mica condensers, transformers, etc.

In *Fig. 1*, a point *O* has been arbitrarily chosen at some place along a parallel wire transmission line, but midway between the two wires. The idea is that if a way is formulated for finding out what is happening in this region, the same data will be good for telling about what is happening throughout the length. The only difference will be that at a point nearer the source all the numbers will be somewhat larger, and nearer the load they will be smaller because of progressive losses which do occur along the line. A coordinate system has been erected about *O* as the origin. The x-axis is arranged to extend along the length of the line and the y-axis therefore cuts across the wires. At the points where the y-axis intersects the wires the peak values of the currents are of course always equal though opposite and are called i_o. At very short distances both before and after the points where i_o is measured, the current will in general be somewhat different. In *Fig. 1*, the current at a distance $\Delta x/2$ before *O* has been called i_1 and the current at a point at a distance $\Delta x/2$ beyond *O* has been called i_2. The radii of the two wires are taken to be r and the distance between their centers is labeled $2a$. The peak voltage between the two wires has also been appropriately labeled at the three points as e_1, e_0, and e_2.

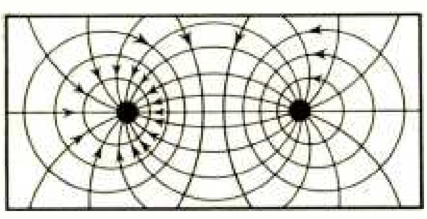


Fig. 2. Electric and magnetic fields of a two-wire transmission line as seen in end view

General Problem

In terms of all these quantities we are now in a position to establish the general problem for long lines. We further define R as the resistance per unit length of the line (i.e., twice the resistance per unit length of one wire), G as the leakage conductance between the conductors, φ as the number of lines of magnetic flux passing between the conductors, and q as the charge present in each conductor per unit length of the line. These last two quantities constantly vary both with time and position along the line. But since we have chosen a particular and very short length of line Δx, we can, to a good approximation, write down an expression for the loss of voltage and current which the line is responsible for in the length Δx. These expressions are

$$e_1 - e_2 = R\Delta x\, i_o + \left[\begin{matrix}\textit{rate of change of flux}\\ \textit{per unit length}\end{matrix}\right]\Delta x \qquad (1)$$

$$i_1 - i_2 = G\Delta x\, e_o + \left[\begin{matrix}\textit{rate of change of charge}\\ \textit{per unit length}\end{matrix}\right]\Delta x \qquad (2)$$

They have been written down by simply asking what it is that can cause the voltage or current to change with progression along the line. In the voltage case this is answered by stating first, that there will be a loss due to the resistance through which the current must flow and, second, there will be a voltage change caused by the building up or tearing down of magnetic fields between the wires. It is well known, and illustrated in every electric transformer, that a voltage can be produced magnetically by a change in a magnetic field. In a transformer, the change in a magnetic field generated by the primary winding causes a voltage to appear across the secondary winding; it is not the strength of the field that determines the secondary voltage but rather it is the fact that it changes. This is the reason that transformers can only be built for alternating current and not for direct current where strong magnetic fields also occur but do not change with time.

Actually, the second term of the right member of equation (1) is closely akin to the idea of inductance as it is commonly known in lumped constant circuits. Because of their changing currents, the transmission lines cause a continual change in the magnetic fields; these changing magnetic fields induce a voltage backward across the line of opposite polarity to that which urges the current to flow. The result is that the net voltage causing the current flow is reduced. This is the nature of the second term of equation (1).

Equation (2) explains why the current i_2 is different from that of i_1 in the same manner. The first term indicates a loss due to leakage between the wires and the second term takes into account the fact that some charge comes to rest in the interval Δx or arises from a charge that was at rest there. The fact that a charge can come to rest along the transmission line is a matter that is closely akin to the action of a capacitance in a lumped constant circuit. Sections of the wires which are directly aross from each other act just like opposite plates of a small condenser, and whenever a voltage appears between them, a certain amount of charge is drawn to their inner surfaces in the same way that voltage applied to an ordinary condenser will cause it to become charged. So far as the current is concerned, it is again a matter of change. The amount of charge stored along the line does not cause the current entering a given section to be different from that which is leaving. But if during the time of observation an additional charge is stored, then during that time some of the current entering the section is diverted for this purpose and the exit current is lessened.

From equations (1) and (2) we wish to obtain a reasonable definition of inductance and capacitance as the terms are applied to transmission lines of this sort and we wish to obtain as simple equations as possible which will describe the voltage and current situation at each and every point of the line for any time.

The mathematical treatment of this can be found in several places[1] and will not be reduced here. Essentially the procedure is to make an approximate calculation of the actual magnetic and electric fields arising from the currents which flow in wires whose size and spacing are given in *Fig. 1.* An approximation comes in for at least two reasons. First in order to keep the equations from becoming too involved it is expeditious to omit terms which are an order of magnitude smaller than the ones retained and second, although for the same reason, components of the magnetic field arising from the so called displacement currents of the capacitance are ignored. It turns out that both these approximations become progressively worse as higher and higher frequencies are encountered. Guillemin, for example, states that for number 10 conductors and 10-inch spacing, a frequency of 152 megacycles is the highest for which reasonable results should be expected from this type of analysis. Although this is a low frequency in terms of microwaves, it is of course many times higher than anything that is met in what might be called classical communication engineering.

As a result of such field calculations we may rewrite equations (1) and (2) as

$$\frac{e_1 - e_2}{\Delta x} = Ri_o + 4\mu tn \left(\frac{a + \sqrt{a^2 - r^2}}{r}\right) \tag{3}$$

[*rate of change of current with time*]

$$\frac{i_1 - i_2}{\Delta x} = Ge_o + \epsilon/\left[4ln\left(\frac{a + \sqrt{a^2 - r^2}}{r}\right)\right] \tag{4}$$

[*rate of change of voltage with time*]

where ϵ and μ are the permeability and dielectric constant of the space surrounding the wires. Incidentally, these equations differ from the first two inasmuch as they have been divided through by the quantity Δx but the important thing is that from calculations concerning the electric and magnetic fields the rate of change terms are now concerned only with voltage and current rather than with charge and flux. In fact, the only unknown quantities in either equation is now that of current and voltage. The fact that an unknown term concerning rate of change occurs is not an additional unknown in itself but only an indication that certain boundary conditions of the problem must be known in order to produce a solution to the pair of simultaneous equations. To find i_o and e_o at any point in a line, not only must a, r, μ, and ϵ be known but also the voltage inserted and the time at which it is done must be given.

It is usual to rewrite equations (3) and (4) once more before attempting to make use of them. They then become

$$\frac{\delta e}{\delta x} + Ri + L\frac{\delta i}{\delta t} = 0 \tag{5}$$

$$\frac{\delta e}{\delta x} + Ge + C\frac{\delta i}{\delta t} = 0 \tag{6}$$

This is possible if we recognize the following equivalences:

$$\frac{e_1 - e_2}{\Delta x} = \frac{\delta e}{\delta x} = \textit{the rate of change of } e \textit{ with } x$$

$$\frac{i_1 - i_2}{\Delta x} = \frac{\delta i}{\delta x} = \textit{the rate of change of } i \textit{ with } x$$

$$\frac{\delta e}{\delta t} = \textit{the rate of change of } e \textit{ with time}$$

$$\frac{\delta i}{\delta t} = \textit{the rate of change of } i \textit{ with time}$$

$$L = 4\mu\, ln \left(\frac{a + \sqrt{a^2 - r^2}}{r}\right)$$

$$C = \epsilon/\left[4ln\left(\frac{a + \sqrt{a^2 - r^2}}{r}\right)\right]$$

The first two of these are only a matter of straight thinking and the realization that $\delta e/\delta x$ is only a notation which indicates rate of change as we have indicated. The quantity $e_1 - e_2$, for example, tells how much change there is in e over a small distance Δx; the change in e in a tenth of an inch, for example. It can be seen immediately that division by Δx therefore gives the change of e per unit length of x or simply the rate of change of e per unit change of x.

The expressions for L and C are definitions. It is fortunate that they come out to have the same sort of use as they would if we used the wires as a lumped unit of inductance or capacitance but that is mere chance or more accurately it is because of that similarity that we name the expressions with the same symbols, L and C which are used for lumped inductances and capacitances.

Equations (5) and (6) are capable of solution in many ways so as to give expressions which tell about the performance of any given parallel wire line in terms of its dimensions, excitation, and load. Books such as the one already mentioned spend hundreds of pages on these various methods of solution. For the purpose of forming physical pictures which can be carried over to u-h-f tank circuits and microwave hollow pipe wave guides, however, it is not necessary (even though advisable) to go through all this in detail. It is only absolutely necessary to realize that equations (5) and (6) are wave equations and that solutions of them will call for currents and voltages in a transmission line to move just as do other waves. If a long stretched string is plucked, for example, a wave carrying energy will travel along the length. The equation of motion of the string can be shown to be given by equations of this general type.

Low Frequency Lines

Before going into the wave picture, however, it is of some interest to quote certain formal results of equations (5) and (6) as they are obtained under the assumption of certain simple boundary conditions. In a standard manner well known to mathematicians as a "solution by the separation of variables", equations (5) and (6) can be made to yield expressions for e and i which, however, in the general case are quite unwieldy and include arbitrary constants which must be fixed in accordance with the way in which the line is excited and the way in which it is loaded.

But if a very long line is imagined, and if we concern ourselves only with a section near the source end of the line so that the line is effectively of infinite length, these solutions for e and i are much simplified and may be written

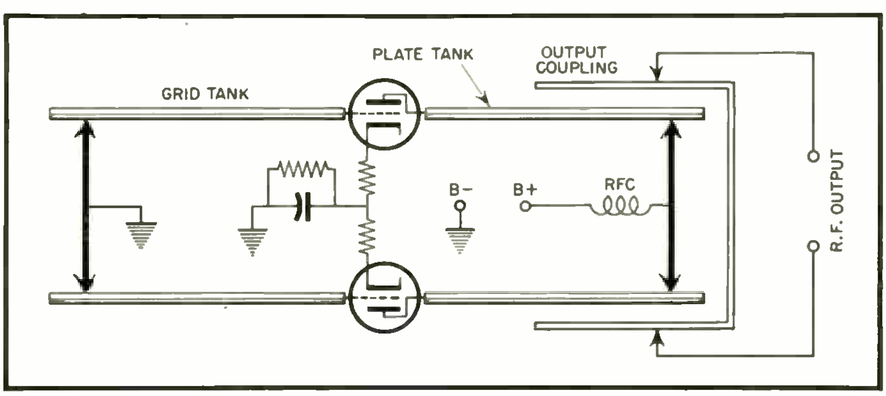


Fig. 3. Schematic of a typical TPTG oscillator which uses shorted sections of parallel wire transmission lines as tank circuits

[1] "Communication Networks" by Ernst A. Guillemin. John Wiley, 1935

so far as their dependence on x is concerned as

(7)

$$e = E\epsilon^{-\alpha x}$$
$$i = I\epsilon^{-\alpha x}$$

where

(8)

$$\alpha^2 = (R + jL\omega)(G + jC\omega).$$

From this it can be demonstrated that α is a complex number which by the respective magnitudes of its imaginary and real parts gives the phase of the sinusoidal variation and the magnitude of the attenuation. In other words, when numbers are substituted for R, G, C, L, and ω, a value of α can be found which has the form

(9)

$$\alpha = aj + b$$

The complex number α is known as the propagation function; the number a is called the phase function; the number b is known as the attenuation function.

If e is divided by i for the case of the infinite line, an impedance function is obtained which is known as the characteristic impedance of the line. From equations (7) and (8) (since time variations unspecified there are the same for both), it may be seen that this is just

(10)

$$Z_0 = \frac{E}{I}$$

The actual values of E and I can be obtained only if the strength of the signal is known. Their ratio, however, is independent of this and without proof is stated to be given by

$$Z_0 = \frac{\sqrt{R + j\omega L}}{\sqrt{G + j\omega C}}.$$

This characteristic impedance, Z_0, which is the actual impedance of an infinite line, is a very important quantity. If, for example, we are given two wires of stated size and spacing, we now have enough information to make use of them in the most efficient possible fashion. First, by the use of the equations given as definitions of L and C, we can calculate those numbers and with them obtain a numerical expression for Z_0. Now, no matter how short our line, if we then arrange our source and load so that they exhibit impedance equal to Z_0, the line will act as if it were infinite in length. This fact is perhaps entirely self-evident only after a thorough study of the properties of traveling waves but it is certainly true and seems reasonable since the matched impedance makes the connections smooth and lacking in any discontinuity which can electrically be interpreted as the end of the line. Thus, after matching to the characteristic impedance, any line acts like an infinite line and a calculation of the attenuation function for the infinite line case will give a description of the way in which a signal is attenuated in its travel along the line.

UHF Lines

In dealing with parallel wire lines as they are used for tank circuits in uhf oscillators it usually becomes impractical to use all the formalism we have just discussed. The general ideas of wave motion along the lines still hold however, and discussions of the currents and voltages or even better of the electric and magnetic fields as waves do explain the operation just as would be expected from an examination of the form of equations (5) and (6).

In *Fig. 3* is shown a typical circuit for a tuned-plate-tuned-grid u-h-f oscillator which uses short-circuited transmission lines as tank circuits. Here, there is no question of obtaining the most efficient possible transfer of energy through the lines. Obviously no energy is expected to emerge from the ends remote from the vacuum tubes because there perfect short circuits appear. One not acquainted with the action of tuned lines might believe that such a short circuit would result in the dissipation of energy into heat. That is what usually happens when a pair of electrical lines such as power lines are shorted. That it does not happen here is because the lines are tuned; they are adjusted in length so that electrically they are just one quarter wave length long. This means that when a sinusoidal voltage is applied to the open end and at some instant demands a current flow in one direction, it takes a time equal to that elapsing during two quarter wave lengths of travel for that current to go the length of the transmission line and come back headed in the opposite direction. During this time the sinusoidal driving voltage has also just had time to reverse its polarity so there is no total disagreement at all as to which way the current should flow.

This is incidentally just the sort of action that is desired of a tank circuit. The purpose of a tank circuit in any oscillator is, first, to time the oscillation and, second, to serve as an energy storage place. The tuned line is a timing device because of the fixed times that are necessary for electrical energy to travel from the open end to the shorted end and back again. Such lines are energy storage places because of the electric and magnetic fields that are built up in great strength from multiple reflections of electrical energy back and forth between the essentially open and the closed ends of the line.

In *Fig. 4* is shown an instantaneous set of values of current and electric field (a measure of the voltage across the line is given by the density with which these field lines are drawn) along the initial portion of a very long transmission line. It is a matter of simplicity of representation that makes us require that the line be very long. If it were not infinite in length or loaded with its characteristic impedance we would not be able to so simply describe with time what happens to the pattern. As it is, we can say that all which we have drawn to symbolize the currents and voltages of *Fig. 4* simply move with time from left to right toward the load. The lines of electric field which we have drawn are the sort of wave motion of which we have been speaking. In terms of them we do not consider flow of one direction in one wire and of the opposite in the other; instead, the quantity of voltage between the wires is a single measurable quantity which moves from source to load and does not return. Closed circuits do not exist for wave motion; they are not needed. To look at the direction of the currents in *Fig. 4* and try to predict how the circuit will appear

[*Continued on page* 60]

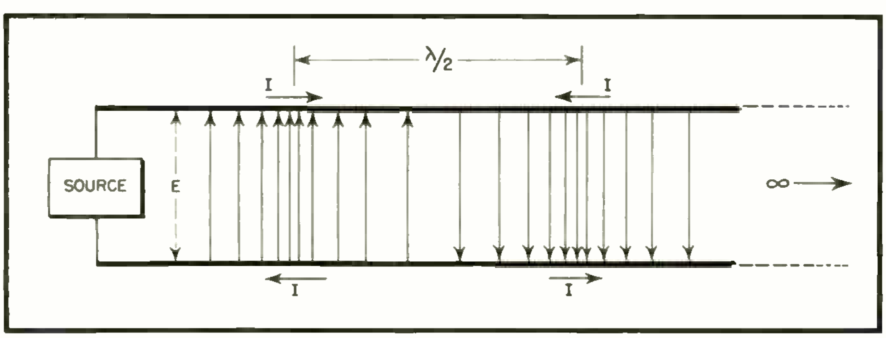


Fig. 4. Current and electric field distribution along an infinite parallel wire transmission line

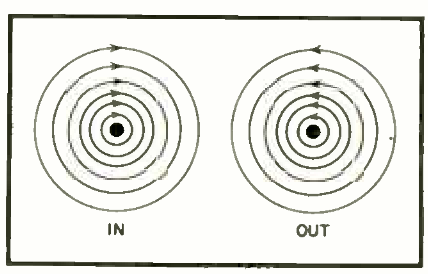


Fig. 5. Magnetic fields surrounding two wires which respectively carry current into and out of the paper. If the two patterns could be entirely superimposed they would just cancel out

NON-LINEAR RESISTORS

A. P. HOWARD

Describing the characteristics and applications of these resistors

CERTAIN materials—apart from those commonly employed in the resistor industry—exhibit peculiar characteristics when exposed to temperature and/or voltage stresses. These materials have been commonly termed temperature-sensitive or voltage-sensitive materials.

The separate effect of temperature is sometimes difficult to ascertain for, with increased current flow and resultant heat dissipation, either the voltage coefficient or the temperature coefficient could be the determining factor.

Consider the case of a typical carbon resistor, which shows properities of both temperature and voltage coefficients. Here we slowly increase the voltage across the resistor with the accompanying voltage coefficient causing a decrease in resistance. At this point increased current is flowing and the unit is heating more rapidly, causing a further decrease in the resistance due to temperature coefficient. This process can be carried on until final destruction of the resistor, without determining cause or effect.

Certain arbitrary assumptions have been made, in order to differentiate temperature from voltage coefficient. Conventional measurements state that temperature coefficient is the property of a material over a wide range of temperatures and with a fixed low potential applied. This causes certain errors in measurements at the upper temperature ranges, but these are not important for our purposes since the ultimate use of these resistor products would have the same errors present.

At the same time, voltage coefficient is based on a fixed temperature with several potentials applied. Here, again, non-linearity is also due to certain temperature influences over a period of time.

Only certain materials can be employed to obtain a temperature or voltage sensitive material. These are limited, at the present time, to the carbon products, ceramic forms, and certain metal oxides or sulphides. The carbon products, such as silicon carbide, exhibit voltage sensitivity to a greater degree than the ceramic or metal oxide. A typical curve of resistance versus voltage is shown in *Fig. 1*. In this case the typical behavior of a carbon resistor is given for reference.

It will be noted upon examination that the resistance changes non-linearly and as an exponent of the voltage or current applied. Certain commercial manufacturers have been able to produce resistors which vary as the eighth power of the current in series, but common commercial substances are more nearly a variant of the third or fourth power of the voltage impressed.

Manufacturing Process

The silicon carbide materials are prepared in several forms: as resistors *per se* or as discs. The raw silicon carbide is mixed with a ceramic binder and pressed to drive off excessive water. This disc or resistor is then uniformly heated. As with the composition resistor, the properties of resistance, temperature coefficient, and voltage coefficient are directly dependent upon the firing temperature and time, molding pressure, and basic constituents.

Because of the non-linear characteristic of the resistor, harmonics can be expected in the output in direct proportion to the current sensitivity of the resistor. As the change with current increases, the harmonic distortion will also increase.

Applications

These materials appear to lend themselves to certain applications. These applications immediately suggested are current-limiting devices, such as shown in *Fig. 2*. All these circuits are basically

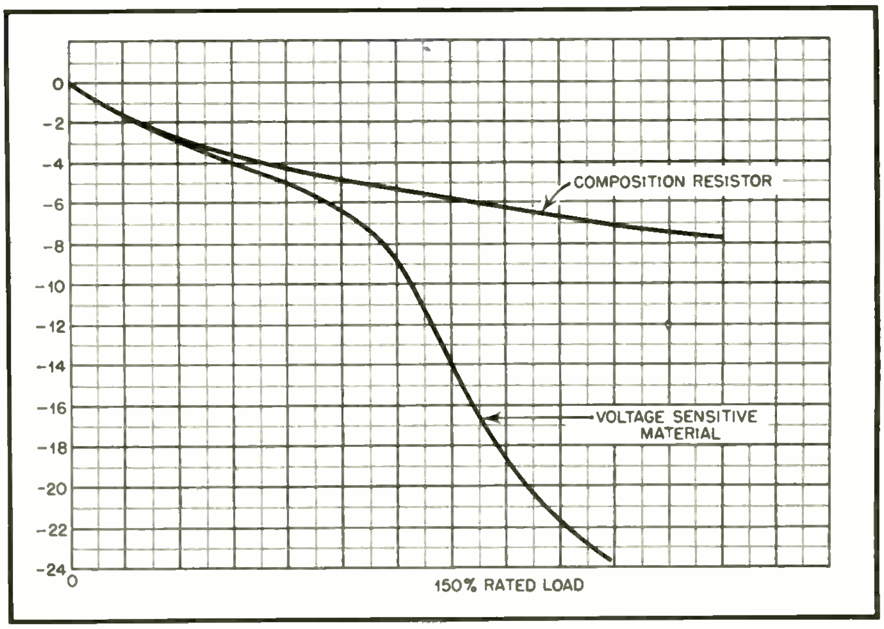


Fig. 1. Resistance vs. voltage curves for voltage-sensitive and composition resistors

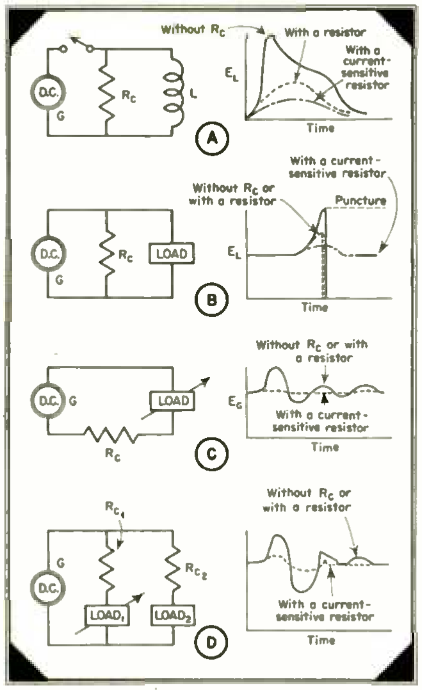


Fig. 2. Current-limiting circuit applications for non-linear resistors

protection devices: *Fig. 2a* shows a silicon carbide material employed to limit the induced voltage after the opening of the switch. As part of the damping circuit, it dissipates a portion of the energy to which the coil insulation would otherwise be subject. *Fig. 2b* shows a shunt limiting device where excessive voltage surges are to be encountered. Because of its relatively instantaneous response, the resistor would not act until the voltage reached the predetermined level, and then drain off the excess current ordinarily damaging to the load. *Fig. 2c* shows a variation of *Fig. 2b* in which a varying load device is in series with the control resistor. Here the effect is that of varying inversely as the load, assuring a uniform load reflected back on the generator. *Fig. 2d* is an extension of the principle of *Figs 2b* and *2c* in which several loads are "evened up" so that the generator sees a constant impedance.

An important consideration in each of the above applications is the circuit in which the unit is to be used. Control, here, is not a simple matter of definition of the voltage-current relationships expected—it is also the result of a complete analysis of the ambient conditions.

Important Factors

The following criteria are the basic ones to be applied in the selection of a current-sensitive resistor: cold resistance, resistance variation desired with variation of current, ambient temperature range, tolerance on both current variations and ambient temperature variations, ambient relative humidity and altitude, temperature rise allowed on the resistor surface, frequency of voltage to be impressed, maximum voltage range, and approximate sensitivity (response time).

To define these current-sensitive resistors as control devices is to limit their active field of operation. Certain other applications are suggested where the use of their current sensitivity is employed in various measuring devices.

The other group of non-linear resistors are those temperature-sensitive devices which are composed of ceramic or metallic oxide forms. It has been known that the ceramic forms identified as kaclin or rutile exhibit large

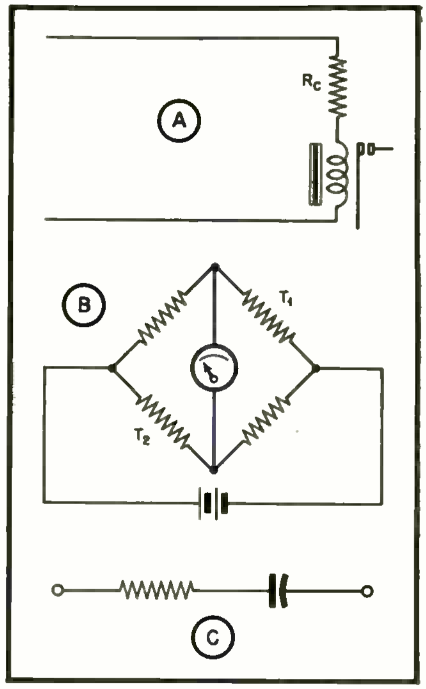


Fig. 4 Potential uses for temperature sensitive relay wound with copper wire: (B), bridge circuit to measure temperature differentials; (C), time delay circuit

temperature coefficients of resistivity and capacitance and, as such, are well suited for such purposes. Certain other experiments have been conducted using uranium and nickel sulphides to obtain the same results.

These materials are far apart from the iron-aluminum-chromium or carbon materials usually thought of as negative-temperature-coefficient materials, as *Fig. 3* indicates.

As ceramic forms, they are fired in paste form at some temperature from 1000°F. to 3000°F. The resultant properties are a product of the mix and of the firing temperatures.

Forms of Heating

Two forms of heating can be employed to utilize the negative temperature coefficient: internal heating by increased wattage dissipation or external stimulus. As such, these resistors present themselves as suitable for several uses: compensation of a positive coefficient of a circuit, part of a measuring device for current or temperature change, or for time delay circuits. Such circuits are shown in *Fig. 4*.

It is apparent to the reader that, upon exploration of the field, the similarity between current-sensitive resistors and temperature-sensitive resistors is great. In many applications, the designer can depend upon either type to perform his work. Care must be exercised that the design is not so close that unproducible tolerances are imposed upon the manufacturer of the material.

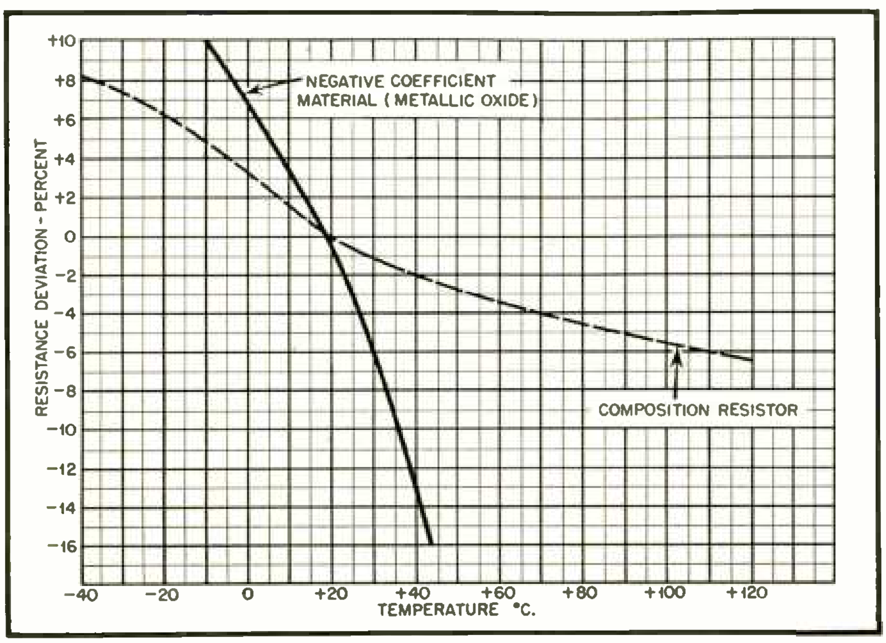


Fig. 3. Comparative curves of negative temperature coefficient materials and composition resistors

FM RECEIVER DESIGN

A. C. MATTHEWS

In this series of articles the author discusses the various factors entering into the design and testing of f-m receivers

PART 2

In our discussion on limiters it was decided that an input of four volts should be sufficient to provide satisfactory operation. Overall sensitivity has also been previously set at one microvolt. To satisfy these requirements, a total gain of 4,000,000 will be necessary.

Probably the most difficult problem in the design of a receiver, where such tremendous gains are required, is to decide how many amplifier stages will be required, how many should be r-f and how many i-f amplifiers. In general, it is more difficult and expensive to obtain gain at r. f. than at i. f.; therefore, r-f amplifiers are mainly employed for image rejection purposes. With this in mind it was decided to use one r-f, a converter and two i-f stages with gains as shown in *Fig. 7*. Such a layout will satisfy our stated specifications. It should be pointed out that in this design the major portion of the gain is concentrated in the i-f amplifier and a very careful chassis layout will be required.

An alternate design employing a double superheterodyne circuit could be used. This would eliminate the need for so much gain at one frequency since one i-f stage would then become a second converter. Such a design has been commercially built but it is inherently costly, and introduces additional tracking problems which tend to balance the advantages of splitting the gain over three frequencies instead of two, as proposed.

I-F AMPLIFIER

The first consideration in the design of the i-f amplifier is the choice of the operating frequency. Several factors influence this choice, namely: spurious response, gain, stability and selectivity.

Spurious Response

These undesired signals result principally from the following factors; (1) poor image attenuation, (2) direct pickup at i. f., (3) two stations whose carrier separation is equal to the i. f., (4) harmonics of the signal and/or oscillator, (5) combination AM-FM receivers.

Considering them in the order listed; the image response is due to the signal combining with the local oscillator to produce the i-f beat frequency, when the receiver is tuned to twice the i-f above or below the normal tuning point, depending upon whether the oscillator is above or below the desired station. This type of spurious response is the same as is experienced in AM receivers; but in the case of an FM receiver, because of the narrow frequency band. images from FM stations in the band can be eliminated by the proper choice of the i. f. Assuming the FM band will have a frequency range from 84 to 102 mc, in order to eliminate images from FM stations, the i.f. would have to be slightly more than 9 mc, since the band is 18 mc wide. While such an i.f. would eliminate images from FM stations in the band it would not protect against images from such services adjacent to the band. Rejection of images from such services would depend upon the selectivity of the r-f amplifier, which will be discussed later.

Another spurious response in the same family is the half i-f image which appears when a signal is at a frequency one-half of the i. f. from the oscillator. It is caused by the second harmonic of the difference frequency being generated in the converter plate circuit which would produe the normal i. f. However, interference from this source is rarely encountered, and will not be discussed at this time.

It appears then from the standpoint of image rejection, the i. f. should be above 9.0 megacycles.

Direct I-F Pickup

Next of importance is the pickup of signals whose frequencies are in the i-f pass-band. Since FM receivers generally employ one or more stages of r-f amplification ahead of the converter, and since the i.f. is far removed from

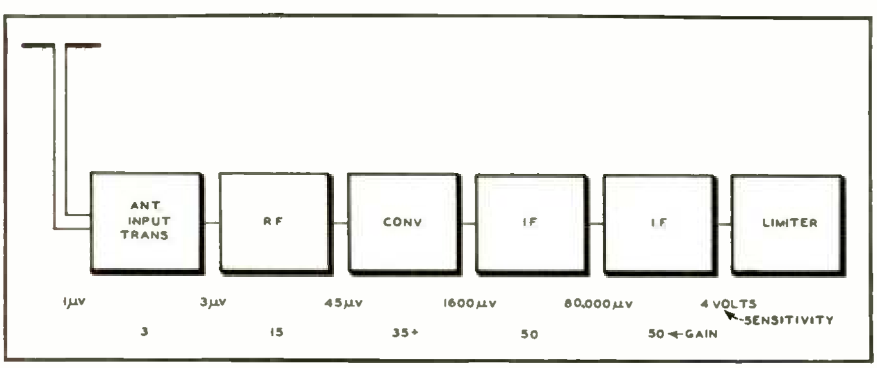


Fig. 7. Block diagram showing gain and sensitivity

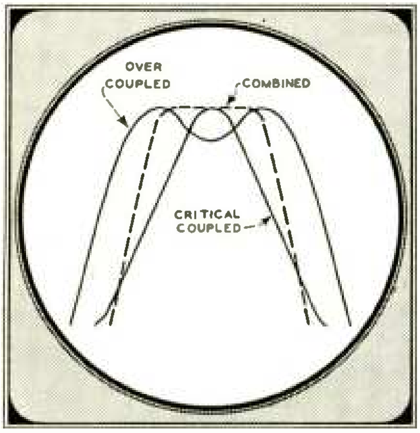


Fig. 8. I-F amplifier selectivity curve

the desired signal frequency, sufficient attenuation is obtained in the r-f stages to practically eliminate this as a source of trouble. But unfortunately, if the interfering signal strength is high, pickup will not be confined to the antenna, and unless the i-f amplifier is well shielded this type of spurious response will be encountered.

From the above it is seen that the choice of frequency is dependent upon two factors; (1) the selectivity ahead of the converter, (2) the shielding of the amplifier itself. The first suggests the use of a high frequency since the higher the frequency the higher the attenuation in the r-f amplifier. The second is not so clearly defined. Looking at it from a production standpoint, it is impractical to shield completely the i-f amplifier, therefore an effort should be made to choose a frequency that is relatively unused, if that is possible, unless the FCC assigns a clear channel for this purpose.

Two-Station Interference

The elimination of the spurious response due to two stations whose carrier frequency separation is equal to the i.f. is merely a matter of making the i.f. slightly higher than the width of the FM band. The use of a lower frequency is advisable only after considering the probability of stations in any one locality being assigned to frequencies having a separation equal to the i.f. and also their probable signal strengths, since the magnitude of the response is proportional to the signal strength. In making the choice of frequency it must be remembered that if this type of interference is present it will be heard over the entire tuning range of the FM band.

Harmonics of Signal or Oscillator

Harmonics of the signal and/or oscillator are often responsible for undesired responses. Harmonics of the local oscillator are inherent in its design and very little can be done to eliminate them except to keep the strength of the oscillator at the minimum required value for good conversion gain. The effect of harmonics of a signal either due to its being generated in the converter or by direct pickup, can be minimized by adequate AVC in the r-f and converter stages. Many designers depend on the action of the limiter stage to provide effective AVC; and while it is true a well-designed limiter will in most cases maintain a constant output over a large range of signal strengths, unless some precautions are taken to prevent overloading of the r-f and converter stages, harmonics of strong signals will occur. It is therefore good practice to include AVC in an FM receiver even though it does complicate the design and is a possible source of regeneration.

The number of spurious responses due to harmonics is difficult to determine since there are so many possible combinations which result in their difference frequency being equal to the i.f. Foster and Rankin[4] have very comprehensively covered the subject and reference should be made to this paper if more information is desired.

Undesired Responses

There are many problems in the design of combination AM-FM receivers which will be discussed under a separate heading. At this point we shall consider only undesired responses associated particularly with combination receivers using two separate intermediate frequencies; one for broadcast and short wave and the other for FM. First, consider the direct i-f pickup. Obviously, if we have circuits in the i-f amplifier which are tuned to two intermediate frequencies, it is necessary that precautions be taken to eliminate the direct pickup in both systems. Shielding, as mentioned previously, can only be provided up to the point where it becomes impractical for quantity production.

After having decreased the direct pickup through shielding we still have two possible sources of interference; the i.f. being used for FM reception and the i.f. required for normal broadcast and short-wave reception. In order to make the combination receiver as interference-free as possible, the unused i.f. should be switched or shorted out of the circuit. This is particularly true of the transformer in the converter plate circuit.

As an example of possible interference, consider the following conditions where no switching is employed. Assume an FM signal at 85 mc, with the oscillator below the signal and intermediate frequencies of 9 mc and 445 kc for the FM and AM bands respectively. The normal FM signal will be tuned in at 85 mc on the dial but weak responses will also be heard at 94.455 and 93.545 mc. These will occur only when the 85-mc signal at the converter is strong enough to produce a beat frequency of 455 kc with the local oscillator, and sufficient coupling exists to the low frequency i-f amplifier. The 455 kc signal is then detected due to the slope of the i-f selectivity curve. Such signals will obviously be distorted, which adds to their annoyance factor. To eliminate this type of interference, circuits or switching must be designed to prevent the low frequency i.f. from receiving any undesired beat frequencies which are inadvertently produced.

Gain

Gain is not a major factor in the choice of the intermediate frequency up to 15 mc. Above approximately 15 mc it becomes more difficult to obtain appreciable gain because the means by which the difficulties are overcome are usually not economically worth while. In general, the lower the frequency, the higher the gain, although with high-transconductance tubes there is no particular design problem. Because other factors have more bearing on the choice of the intermediate frequency, gain will not be considered further.

Stability of Frequency

The stability of an ordinary tuned circuit is almost inversely proportional to frequency. In other words, as the resonant frequency of a tuned circuit is increased the stability will decrease, due mainly to losses in the insulating materials of the component parts. This being the case all insulating materials should be of the highest quality. Coil forms should be of the low-loss material and have adequate impregnation or other treatment to nullify changes due to temperature, aging or humidity effects. The tuning condensers must also be extremely stable under these conditions. The specification of silver-plated mica or temperature compensating condensers as the

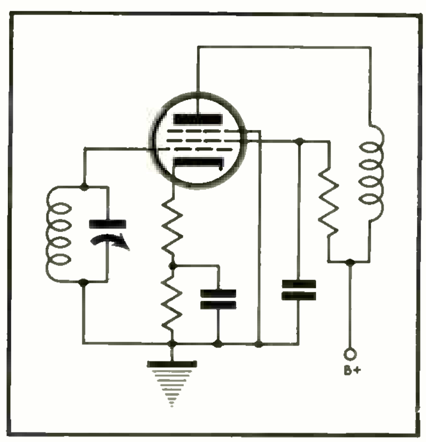


Fig. 9. R-F circuit, showing unbypassed cathode resistor to increase effective input impedance

major portion of the required capacity, leaving only sufficient variable capacity to compensate for circuit wiring and tube capacity tolerances, is good practice.

From a circuit stability standpoint it evident that the choice of the i-f should lean toward the lower frequencies so far as is consistent with other factors.

Selectivity

In general, the selectivity or bandwidth will not be affected by the operating frequency if the effective circuit Q of the stage is increased in proportion to the increase in frequency. For example, if the bandwidth of an i-f stage is 200 kilocycles at 2 mc, and it is desired to increase the operating frequency to 8 mc and maintain the same bandwidth, the effective or operating Q of the circuits must be increased four times. Since FM receivers require relatively wide-band amplifiers having low Q circuits, it is entirely feasible to increase the circuit Q and obtain the desired bandwidth at frequencies as high as 20 to 30 mc. Above 30 mc difficulties are likely to be encountered due to insulation losses, low tube input impedances and stray couplings which might result in regeneration.

From the above it can be seen that selectivity is not particularly a controlling factor in determining the frequency of the i-f amplifier, because the design parameters are all within a reasonable range of practicability.

Summarizing, we find for image rejection the i-f must be higher than 9 mc; bandwidth requirements are not critical as to the choice of i-f up to perhaps 30 mc; circuit and regenerative stability favor low frequencies; gain requirements are not especially critical but favor a low frequency, and direct pickup interference depends on the particular locality. A choice of 9.1 mc as the intermediate frequency for FM receivers seems to satisfy adequately the requirements outlined. (This is based on the band being 84 to 102 mc).

Having decided on the frequency, we should next consider the choice of the tube to be used.

Choice of Tubes

Thompson[3] has shown that the limiting condition for stability of a single stage r-f amplifier is where the feedback capacity from grid to plate is less than $2g_1g_2/\omega g_m$; where g_1 and g_2 are input and output conductances and g_m is the transconductance of the tube. From this it is evident that the important characteristics to consider in the choice of an i-f amplifier tube are the grid-plate capacity and the transconductance.

Omitting operating parameters such as plate, screen, control grid and filament voltages, a list showing g_m and C_{gp} of several prospective tube types has been compiled.

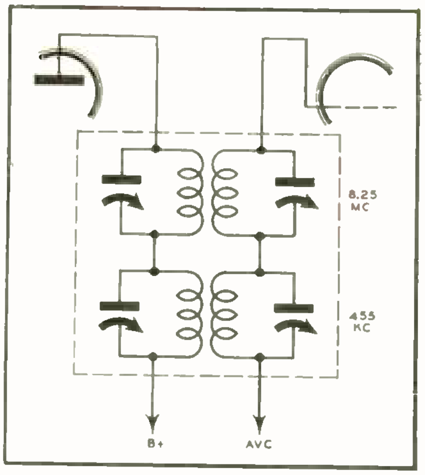


Fig. 10. Combination i-f transformer

Type	g_m	C_{gp}
7W7	5800	0.0025 $\mu\mu$f
6SH7	4900	0.003 "
6SG7	4700	0.003 "
6SK7	2000	0.005 "
7G7	4500	0.007 "
6AC7	9000	0.015 "
6AG5	5000	0.025 "
6AG7	11000	0.06 "

Taking the ratio of the transconductance to the grid-plate capacity as a figure of merit it is seen that the 7W7 would be the preferred type of tube for the i-f amplifier. In this tube we have comparatively high transconductance (high gain) and extremely low grid-plate capacity (low feedback). The input and output capacities are also within usable limits which permits the use of reasonable large inductances in the tuned circuits.

It should be pointed out at this time that high transconductance tubes usually have a sharp control-grid cut-off characteristic and, in general, do not lend themselves to good A-V-C action. This is not so important for FM reception where a limiter is used, because only a small amount of A-V-C is necessary. But in a combination AM-FM receiver, good A-V-C action is required to prevent distortion at high signal levels in the AM band. While the A-V-C circuit can be switched along with the bandswitch, this will add to our switching problems. It is better design practice to dispense with the additional switching and include A-V-C in both the AM and FM bands, since it will cause no harm on FM and is definitely required for the AM band. Satisfactory A-V-C action can be obtained with sharp cut-off tubes by operating them with a series screen resistor. This will extend the cut-off point from three to five times its normal value, but will also limit the gain to approximately 80 per cent. By carefully proportioning the A-V-C a compromise design can be obtained which will be satisfactory for AM and with negligible loss in FM gain.

Maximum Gain per Stage

Assuming high transconductance tubes with high input impedance and high impedance tuned circuits, the maximum stable gain per stage is limited by the amount of feedback present. This can be a serious factor in an FM receiver where high gains are required to operate a limiter stage. Possible sources of feedback to be considered are (1) grid-plate tube capacity, (2) common coupling in the power supply circuits, (3) extraneous stray coupling between stages, (4) ground currents in the chassis and wiring.

The effect of feedback due to grid-plate capacity has been previously discussed and in choosing the tube type for the amplifier this was taken into consideration.

Common coupling in the power supply circuits can be minimized by the use of RC filters in the plate, screen and grid supply circuits. Care should be taken to keep by-pass condensed leads short because at these frequencies long leads nullify the by-passing effect of the condenser.

Extraneous coupling between stages can be made negligible by complete shielding, although this is impractical in quantity production. It is necessary then to minimize stray coupling by careful chassis layout and judicious "dressing" of critical leads. By-pass condensers with the outside foil at ground potential can often be placed to provide a limited amount of shielding. In spite of all precautions, it is nearly impossible to obtain the maximum theoretical gain from an i-f amplifier without complete shielding.

Ground currents in the chassis and wiring are particularly troublesome from a feedback standpoint because they are difficult to eliminate. Production requirements are such that it is not practical to return all ground leads or bypass condensers to one point, it is therefore necessary to use numerous wiring terminals and ground lugs which obviously introduce common impedance paths. No set rules can be given to alleviate the situation since every design has its own particular "fix".

Taking all of the above sources of feedback into consideration a maximum i-f gain of 50 per stage with a 7W7 type tube is about the limit for a good production design.

Over-coupled double tuned transformers are generally used. The flat top characteristic being obtained by damping resistors. An increase in gain can be

[*Continued on page* 60]

COMMUNICATION

A comprehensive survey of various types of relays, with practical data regarding their characteristics and applications in radio apparatus

All the relays described in a previous issue* are fundamentally alike in operation but the excellence of design proportions can only be judged by tests which duplicate service conditions.

Service Complaints

A typical relay may exhibit the following defects in service: The contacts stick; this would mean that the contacts, after closing and switching the power to the load, will not open again when the control voltage is removed from the operating coil. When the coil has been energized, the contacts close but voice signals do not get through; this is due to an insulating film of corrosion or dust which prevents metallic contact. When used in mobile equipment, serious noise and voltage pulsations are noted in circuits which are in series with the contacts; this is caused by insufficient pressure between contacts to keep them closed against the accelerations caused by small jars. Whenever a nearby motor drive is started up, the equipment already in operation stops momentarily; this is due to the relay armature falling back to the unenergized position because the pull exerted by the coil was reduced by the voltage drop caused by the inrush load of the motor drive. A control relay, which has been operating at very high ambient temperatures. has the coil voltage removed momentarily and upon restoration of the coil voltage will not pull-in again; this is due to overheating of the coil to such an extent that the increase in copper resistance reduces the current to a point where the effective ampere-turns of the coil are not sufficient to cause pull-in of the armature.

For an engineer to make an estimate of the excellence of workmanship of an article, the criteria he will use will have been formed by his knowledge of the effect that certain features and materials will have. Until the advent of communications and remote controls in mobile equipment, aircraft and compact portable instruments, there was no need to consider the use of a relay except in one steady position. An important point which the old-time designers did not overlook was that while a spring may break due to corrosion or fatigue, gravity has never been known to fail. Therefore, many of their designs had the moving parts deliberately unbalanced to gain the helping hand of gravity. Although the purpose of this method was well understood, a trend of thought, once established, is difficult to break. Consequently, recent investigations of relay applications have shown many gravity-return or gravity-aided-return types being misused in pre-production models. Experience is a hard teacher and the lessons learned by service failures have resulted in the formulation of a set of specification requirements called *Service Conditions.*

Fig. 1 Struthers-Dunn Type 17AXX balanced armature relay

The first group which officially issued such a set of requirements was the Civil Aeronautics Authority. Radio communication has been indispensable to the practical operation of commercial aviation. Naturally, the first rigs to serve in aircraft were not much better than what the amateur used. These requirements were the first to define a general test for resistance to vibration under conditions of varying frequency and different amplitudes. Also included was a test for ability to withstand shock. This shock test consisted of dropping the entire equipment on the top of a table. The intensity of the shock, judged in terms of acceleration, was quite variable and not reproducible with any accuracy.

Next to feel the necessity of preparing against new environments was the Army Air Forces. High altitude flying brought low air pressure and very low temperatures as its companions. The low air pressure increased the severity of contact arcing and the low temperatures congealed the lubricant used on the armature bearings. The activity of the Army Air Forces and Army Ground Forces in the past three years in desert and jungle areas has brought the intense heat of the desert at noonday, and the always damp, always warm atmosphere of the jungle. The usual permissible temperature rise, upon which the power rating depends, must be decreased because of the high ambient temperatures of the desert.

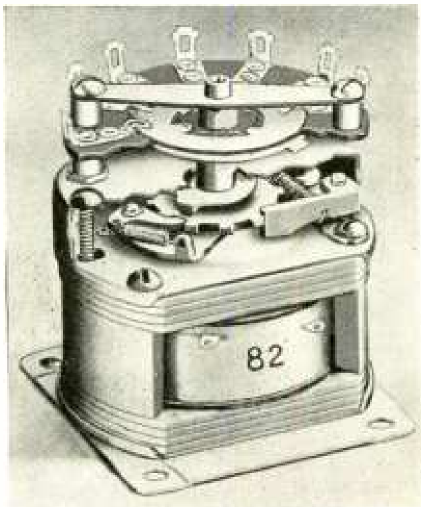


Fig. 2. "Ro-Trol Stepping Unit," Type 82 *(Courtesy Price Brothers Co.)*

* Radio, March, 1945

and CONTROL RELAYS

GEOFFREY HERBERT **PART 2**

Moisture absorption reduces the dielectric strength of the insulating materials and the water condensation acts as the electrolyte to speed corrosion of wire and frame. The constant moist warmth encourages the fantastic growth of living creatures. Fungus which troubles us only slightly in temperate climates becomes a ravenous vine in the tropics, existing on all forms of organic insulation which have not been produced synthetically.

The result of these new challenges has been for the Services to widen the scope of the Service Conditions until every possible extreme of usage and climate has been guarded against by suitable trial and proof of ability to take it.

Since it is not convenient to wait a year or two until the equipment has been in service long enough to warrant a judgment being passed on its worth, the tests prescribed in the specifications are of the accelerated type. This method of testing concentrates the probable average experience of a piece of equipment into a few hours, or at most a few days, by increasing the severity of the test conditions or increasing the rapidity with which the cycling is repeated.

These qualification tests and the manner in which relays are prepared to meet them are discussed.

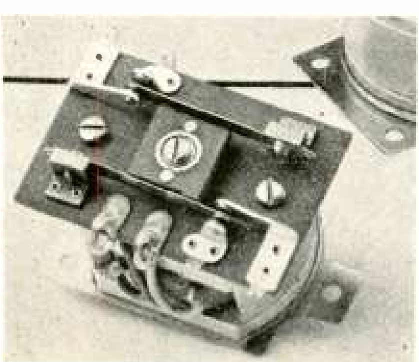


Fig. 3. "Ro-Trol Relay", Type 311
(Courtesy Price Brothers Co.)

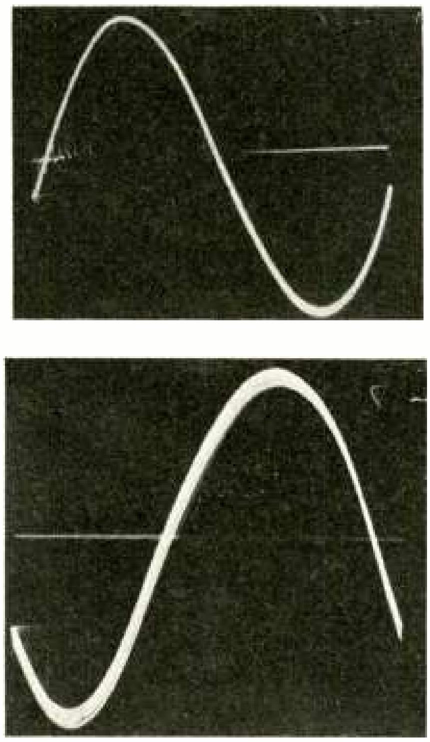


Fig. 4. Oscillogram (top) of rebouncing relay contacts and, (bottom) the clean trace resulting after treating the contacts
(Courtesy Allen B. Dumont)

Vibration and Shock

The emphasis placed upon vibration in connection with relays is not excessive. Most of these tests actually tell more about a relay than the title of the test would indicate. The vibration test not only shows the amount of acceleration which the contacts will stand without chattering, but also proves the ability of the frame to withstand shock.

Shock and vibration are similar in that both subject a part to severe accelerations which involve proportionate mechanical forces. This means that in the case of a relay subjected to an acceleration of 10G, the individual parts are being pulled away from their points of attachment by a force equal to 10 times the pull which gravity exerts on each part. The principal difference between a shock and vibration is that the shock is a heavily damped train of vibration of which only the first cycle is significantly large. Because of this similarity, most tests are confined only to vibration unless violent shocks are probable.

In *Fig. 1* is shown a basic design which is the ideal in simplicity and yet will withstand acceleration forces up to 90G. The secret of its success is the perfect balance of the moving parts. In general, all of the new relays will be found to be fairly well balanced though not perfectly. This is due to compromises of space and arrangement which affect good balancing. No balancing would be necessary if the magnetic coil had sufficient pulling power, but this would be a very inefficient and clumsy way of doing it. Since the average mobile power supply is subject to quite wide voltage output fluctuations, the power on the magnetic coil can drop severely.

By way of a side light on well balanced relays, in *Figs. 2* and *3* are shown a new style of relay construction which embodies this principle and at the same time secures a more efficient magnetic motor. In this design the armature is pivoted at its midpoint on a shaft which also drives the contact springs or rotor of a wafer switch. The magnetic flux passes up through the center of the armature and out through the two opposed arms. This produces a balanced torque couple on the armature shaft and permits a convenient symmetrical arrangement of contacts. Therefore, the entire moving structure is in complete static balance. For the D.P.D.T. contact arrangement in *Fig. 3* the coil power would be 1.2 watts. Also this driving mechanism lends itself to a ratchet type drive for stepping a rotary switch through twelve positions.

The consequences of failure to meet vibration and shock are these:

Mechanical supporting parts may be bent, thus completely stopping operation or changing adjustments sufficiently to seriously affect reliability. The performance of that part of the equipment which receives its current through the relay contacts may behave erratically or unusably due to the chattering of the contacts. This chattering of the contacts under load also damages the contacts of the relay. The rapidly repeated openings of the contacts burn them quickly away and reduce the life of the relay.

Vibration Test

The relay shall be subjected to simple harmonic motion applied to the mounting base. The amplitude shall be 0.03 inch (total excursion 0.06 inch) and the frequency shall be varied uniformly from 10 to 55 cycles per second and back to 10 cycles per second, the period of variation being approximately from 1 to 10 minutes. The relay shall be mounted horizontally and vibrated continuously for three hours. The test shall then be repeated with the axis revolved to 90 degrees to the original axis and again with the relay mounted vertically. At least one of these tests shall be conducted so that the plane of vibration is parallel to the plane of contact travel. Test lamps or suitable indicating devices shall be connected across the terminal contacts while the circuit breaker is undergoing this test to determine that the vibration does not change the required contact positions. During half of each three hour period the coil shall not be energized. During the other half period, the relay shall actuate the contacts satisfactorily with 18.0 volts across the coil and shall stay actuated when the voltage is reduced to 9.0 volts.

The voltage values in the test above were for a nominal 24 volt power relay. A neon lamp or oscilloscope is much more sensitive for detecting slight contact chatter than an incandescent lamp. An incandescent lamp is especially unsuitable for use on contacts which are closed.

Shock Test

The relay shall be secured to a sufficient mass, in each of its rectangular positions, in turn, subjected to a transient deceleration produced by dropping the assembly through a sufficient height that when decelerated by resilient impact, a deceleration of 25 gravity units shall be obtained. An oscilloscope or other suitable test method shall be used to determine that the contacts remain in their required positions with the coil not energized and with the coil energized at 27.5 volts. The duration of any chatter shall not exceed 0.002 seconds as measured on the oscilloscope or by equivalent means.

Coil Voltage

The problem was discussed partly under Vibration and Shock because of the relationship of the two. The major reason for the severe pull-in and hold-in requirements is the combination of circumstances that takes place in aircraft. During the starting period, only the batteries are supplying power and the voltage drop due to the heavy current inrush associated with the starting of direct current equipment is great. For relays which control the main power to such a piece of equipment this can be very dangerous. If the relay coil is deriving its voltage from the same power supply line, the voltage drop due to this inrush may cause the contacts to drop out while carrying this peak load. As the load is broken the voltage on the relay coil will rise again and relay contacts pull-in. This sequence of operations will repeat until either the equipment has come up to running speed or the relay contacts have welded together due to heating and pounding against each other.

Another hidden source of coil trouble is not due to voltage but to an increase of copper resistance caused by the temperature rise of the coil itself while operating plus high ambient temperatures. The change of copper resistance reduces the effective ampere-turns of the coil, thus its pull-in and hold-in voltage are not as safely low as before.

Coil Voltage Test

The relay coil shall be continuously operated for one hour at an ambient temperature of plus 71 degrees Centigrade (plus 160 degrees Fahrenheit). The relay armature shall not drop-out and the contacts shall be in their required position when the coil voltage has been reduced to 7.0 volts. Immediately after the circuit has been opened the relay armature shall pull-in again and the contacts be in their required position when 18.0 volts, or less, is applied to the coil.

These values are for a nominal 24-volt d-c power relay.

Coil Current Consumption Test

The coil shall not consume more than the rated current when operated at 29.0 volts at plus 25 degrees C. (plus 77 degrees F.) for approximately one hour.

Contact Rating — Carrying

It is quite common to assign a nominal rating of 100 amperes (for example) to a relay. This figure must

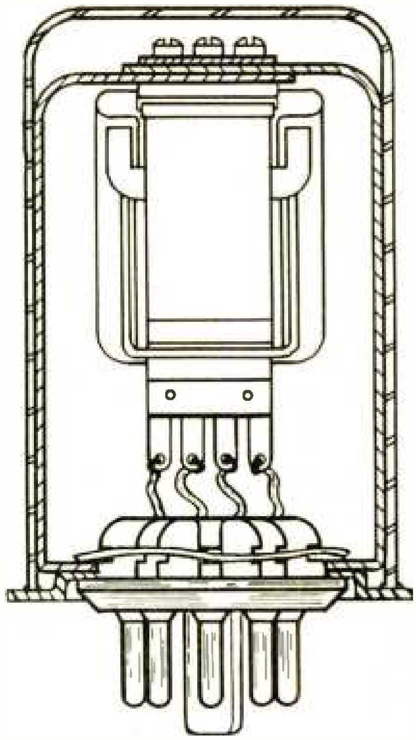


Fig. 6. Hermetically sealed relay.
(Courtesy Allied Control Co.)

be modified for each type of load, duration of load and life expectation as measured in number of operations. The current which the contacts will carry continuously without destructive heating is usually used as the nominal value. As a general rule for intermittent duty, the contacts should be capable of carrying 150 per cent of the nominal value for five minutes and 200 percent of nominal value for one minute.

The choice of the material used for the contact and the size of contact are determined by trial and experience. For most small power relays, fine silver is the best all-round choice. It has excellent electrical conductivity, negligible corrosion, and a low rate of wear due to arcing.

Larger power relays, whose contacts must interrupt heavy loads, use silver alloys containing a small percentage of cadmium oxide, nickel or tungsten either to reduce the severity of the arc or to give the alloy more resistance to the heat of the arc. Gold or alloys of the platinum family are usually employed for signal circuits where circuit voltages are very low.

In the production of multiple contact relays it is important that the contacts open and close uniformly. The air gaps are checked by means of feeler gages and the contact pressure by a leaf-spring type scale. A sufficient amount of contact pressure assures two things. The average silver contacts will form a film of corrosion and tarnish after exposure to the air and arcing. By having sufficient pressure, this film

Fig. 5. Dust sealed relay
(Courtesy Allied Control Co.)

of insulating materials is easily penetrated and a low contact resistance can be secured. On multi-contact relays, each contact is spring mounted to permit them to compensate for slight misalignments. Because of this resilient mounting, there will be a tendency to chatter under vibration and shock. This tendency is diminished by the amount of pressure with which the contacts are held in place.

Contact Rating Test

The voltage drop across the contacts must not exceed 0.1 of a volt with a load at rated voltage (27.5 V.d.c.) and current (100 A.) across the contacts.

Make and Break

It is not easy to determine what is a safe, conservative make and break rating for a relay contact because of all the variable factors which affect the operation. Whereas the carrying rating depends principally upon the allowable heating due to resistance, the make-and-break ratings depend upon the character of the load, the type of current, the degrees of contact bounce, the ability of the contact material to withstand arcing, the speed with which the contacts open, the size of the contact gap, and the density of the air. The share of the rating for which each condition is responsible is practically impossible to calculate. But the result of these combined factors determines the rate at which the contact is burned away.

The amount of contact material which can be burned away before the carrying capacity is lost determines the number of operations which can be expected from the relay. This number of operations is the measure of the life of relay. A contact rating for make-and-break service is meaningless without also specifying the minimum number of operations. The longer a relay can operate without the loss of the contact area and contact pressure upon which the carrying capacity is based, the more conservative is its rating. Therefore, the selection of the make and break rating must be a compromise with the number of operations desired.

Resistive loads are those such as electrical heaters and incandescent lamps. An electrical heater draws the same current when the contacts are closing, closed, or opening. An incandescent lamp has an inrush current of about ten times normal current. Inductive loads are those such as electrical motors and solenoids. Electrical motors have inrush currents and stalled currents of 5 to 10 times running current. Solenoids have low inrush currents but like electrical motors have the property of producing induced voltages into the circuit when the contacts are opened. This causes the contacts to open under an abnormally high circuit voltage which contributes to serious arcing. To duplicate these various conditions, the relays are tested with resistive and inductive loads at rated current and with a resistive overload to simulate inrush currents.

Contact Rating Test — Inductive Load

One relay shall be subjected to 20,000 cycles of operation at 50,000 plus or minus 2,000 feet at rated voltage and current with a standard inductive load at 20 cycles per minute. The "on" and "off" periods shall be approximately 1.5 seconds each. No complete failure shall occur and at the completion of this test the drop across the contacts shall not exceed 0.1 of a volt at rated voltage and current.

Contact Rating Test — Make and Break — Resistive, Overload

The second relay shall be tested for making and breaking eight times the rated load at rated voltage for 50 operations at a minimum "on" period of 0.15 of a second and a maximum "off" period of 3.0 seconds, without welding of the contacts.

Contact Rating Test — Make and Break — Resistive Load

The relay shall then be subjected to 50,000 cycles of operation for making six times the rated load at rated voltage with the coil voltage dropping to 12.0 volts upon make and then break the normal rated load. The contacts shall operate approximately at the rated voltage during the fluctuations of the coil voltage. The "on" period shall consist of a minimum of 0.25 of a second and the maximum "off" period shall be 1.25 seconds. The operating cycle may be increased provided that the test conditions as specified may be simulated. During the "on" period the surge current shall not be less than 0.05 of a second.

Contact Resistance

The relay shall then be subjected to 50 more cycles of operation in accordance with the preceding overload test and at the completion of this test the drop across the contacts shall not exceed 0.1 of a volt at rated voltage and current.

Ambient Temperatures

Extreme temperatures may affect the materials used in the relay sufficiently to cause complete failure. The most likely difficulty is that the differences in the coefficient of expansion for the various materials may cause binding of the moving parts. If a lubricant is used on the sliding parts, it may increase in viscosity until the torque available is insufficient to overcome the drag. The effect of high temperatures on coil resistance and operation was already discussed under coil voltage. Therefore, it is not necessary to test again at high temperatures. It may prove useful to remember that the copper resistance continues to drop with lower temperatures and the coil current consumption will rise more than 50 per cent.

Low Temperature Test

The relay shall be subjected to minus 54 degrees Centigrade (minus 65 degrees Fahrenheit) for a minimum period of 16 hours. At the end of this period and with the relay at this temperature, the relay shall be tested for conformance to the specified pick-up and drop-out voltages.

Humidity and Salt Spray

The moisture in the air inevitably finds it way by condensation onto the insulation of the coil and contact insulation. There it lowers the dielectric strength of the insulation and promotes corrosion of the copper wire of the coil. This is due to the fact that when moisture is in contact with insulating paper for a long period of time chemical decomposition of the paper occurs, releasing organic acids which attack the copper. This is further aggravated by the presence of electrical potentials across the coil and contacts. The acids in water solution act as an electrolyte. The resulting flow of current through this electrolyte quickly dissolves the copper wire away. The finer the wire, the more likely is failure from this cause. Most manufacturers impregnate their coils thoroughly with varnish so that moisture cannot find an absorbent medium. An excellent alternative method is to use cellulose acetate foil as the inter-layer insulation for the coil winding instead of paper. Cellulose acetate is a neutral thermoplastic which does not decompose in the presence of water and has excellent dielectric strength even when wet. It also has the desirable property that it can be heat sealed. By winding the coil so that the edges of the cellulose acetate interlayer insulation extend about one-sixteenth of an inch beyond the wire, the completed coil can be pressed against a polished hot plate at both ends, sealing the coil against almost everything except total immersion. This use of a plastic film does not require any additional treatment to resist fungus. Coils which use paper insulation and paper or cloth based phenolics must have a fungicidal varnish applied over them after fabrication.

Humidity Test

The relay shall be subjected to a relative humidity of 95 to 100 per cent at a temperature of plus 40 degrees Centigrade, plus or minus 2 degrees (104 degrees Fahrenheit, plus or minus 3.6 degrees), for a period of 30 days. During this test a potential of 150 volts, r.m.s., at commercial frequency, shall be applied between terminals and other exposed metal parts. There shall be no insulation failure as a result of this test. Immediately after this test the relay shall be subjected to and shall satisfactorily pass the applicable operating voltage test specified herein, and then shall be subjected to 10,000 continuous cycles in accordance with the resistive load test, without welding of the contacts.

Salt Spray Test

The relay shall be subjected to a 25-hour salt spray test. At the completion of this test the relay shall satisfactorily pass the applicable operating voltage characteristics in accordance with the tests specified herein and shall satisfactorily operate 10,000 continuous cycles in accordance with the resistive load test without welding of the contacts.

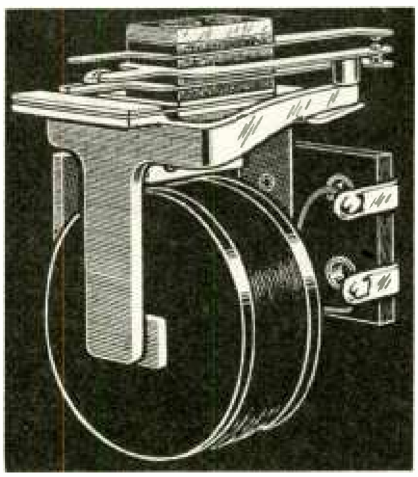
Sand and Dust

Sand, dust, dirt and grit are everywhere. The only reason that they are ignored so frequently is that they are so common. But they are extremely destructive. On a relay they may jam the moving parts by lodging between closely fitted pieces. But many relays are not too susceptible to jamming because of the loose fitting and extremely simple design of the armature hinge which allows no places for the dust to settle. The contacts, though, are frequently affected by dust or sand settling in a thin film across their surfaces. When the contacts attempt to close, the dirt is sufficient to insulate them from each other. Although the relay itself is not damaged, this is equivalent to complete failure of the relay. Occasionally the dirt only prevents the contacts from making contact over a sufficient area. This will cause extra heating of the contacts and a greater voltage drop. Unfortunately the heating can be so great as to weld the contacts together. One of the techniques of the industrial manufacturers is to design their apparatus so that the plane of the contact faces lie in a vertical plane. Dirt cannot cling to a vertical face as heavily as on a horizontal face and the trouble due to dirt is mininized.

Fig. 8. Sigma sensitive relay. Type 5R

Balanced armature relay

(Courtesy Struthers Dunn)



Clare 400-cycle relay

Sealing

Designers have used almost every artifice they know to improve the reliability of the relays. They have developed designs of armature and contact arrangement which make a relay immune to vibration and shock. They have proportioned the magnetic structure and coil to withstand coil voltage variations and temperature extremes. But they were not able to do anything about the weather. The weather for a relay is the change in air density with altitude, and the moisture and dirt which is air borne. Air at lower pressures ionizes easily and lacks the arc quenching properties it displays at sea level. The evils of dirt, moisture and fungus are difficult to evade completely.

Lately, the principle of hermetical sealing has become popular as a cure-all for these troubles. Essentially it consists of an air tight can, which will not leak at pressure differences up to 1 atmosphere, into which the relay is mounted. The electrical connections to the relay are made through sealed insulating terminals of metal fused to glass. In *Figs. 5* and *6* are shown representative types of construction. In the smaller relay mountings the terminal seal is similar to that used by manufacturers of metal tubes. In the larger relays, individual terminals, made of glass fused to a metal lead-in and an outer metal band, are used. The outer metal band is soldered to the case.

These relays are prepared by carefully drying for several days in a chamber before putting into the can. The relay is attached to a bracket which is fastened to the base of the container and the internal connections are made between the relay and the sealed terminals. The cover is slipped over the top and induction soldered to the base. The pressure of the air in the case is then approximately at sea level and remains constant for the life of the relay. Occasionally, the can may be filled with some other gas, such as helium or hydrogen.

In *Fig. 7* is shown a dust-tight construction which, while it protects the relay from dirt carried by the air, does not maintain the pressure inside the can. Pressure changes in the surrounding air due to altitude and barometric changes will cause the can to breathe. Changes of temperature which accompany changes of pressure may then cause the moisture in the breathed-in air to be condensed inside the can. After several breathing periods sufficient moisture could collect inside the can to be troublesome. The advantages of a tight-fitting container which is not pressure-tight are very dubious.

This Month

A. T. & T. ANNOUNCES SITES FOR RADIO RELAY STATIONS

The A. T. & T. Company moved ahead on its trial of microwave radio transmission today by filing application with the Federal Communications Commission for authority to construct seven relay stations between the terminals of the New York-Boston radio relay project. FCC approval on the two terminals was granted last year.

Purpose of the trial is to determine in practical operation the relative efficiency and economy of radio relay for transmission of long distance telephone messages and of sound and television programs, compared with transmission over the familiar wires and cables and the recently developed coaxial cable.

Bell System scientists view radio relay as a promising means of attaining very broad bands of transmission which can be carved up into different channels for telephone and telegraph messages and for sound broadcast and television programs. A technique by which this can be done on the new coaxial cable systems has already been developed by Bell Telephone Laboratories.

Sites for the relay stations, about 30 miles apart, were chosen for their elevation. This not only takes into account the fact that microwaves do not travel much farther than the horizon, but it also puts the transmitting and receiving antennas well above intervening obstructions so that the waves can be beamed from hill to hill.

The intermediate stations will be built on the following sites, reading from left (New York) to right (Boston) on the map:

Jackie Jones Mountain, 35 miles up the Hudson from the New York terminal in lower Manhattan. The mountain, west of the river, is in Haverstraw Township, 5 miles west of Stony Point, N. Y.

Birch Hill, in Patterson Township, 5 miles southeast of Pawling, N. Y.

Spindle Hill, in Wolcott Township, 4 miles southwest of Bristol, Conn.

John Tom Hill, 7 miles east of Glastonbury, Conn.

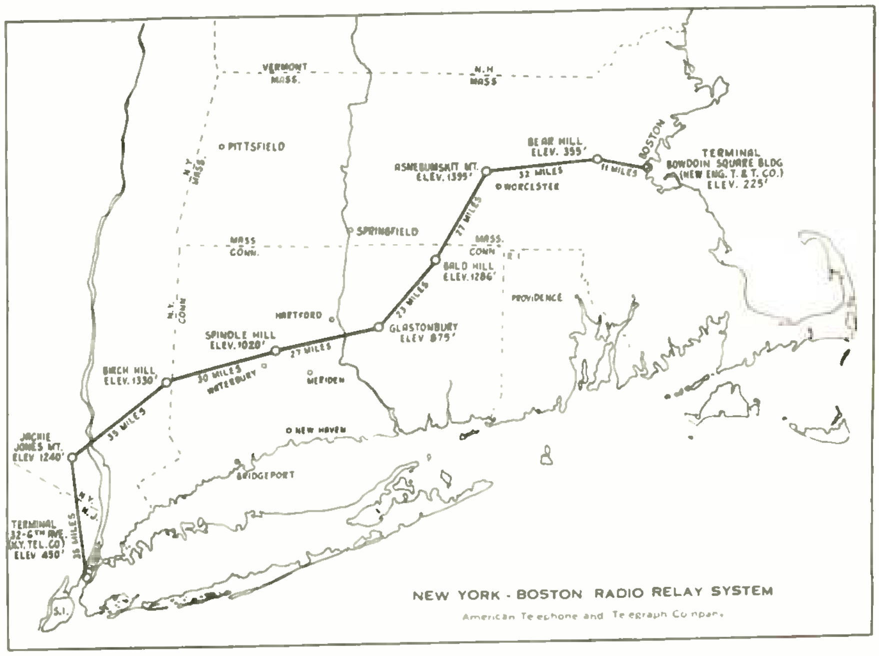
Bald Hill, in Stafford Township, 3 miles east of Staffordville, Conn.

Asnebumskit Mountain, in Paxton Township, 5 miles northwest of Worcester, Mass.

Bear Hill, one mile northwest of Waltham, Mass., and 11 miles west of Boston.

The New York terminal will be atop the A. T. & T.'s Long Lines Building at 32 Sixth Avenue, while the Boston station will be on the Bowdoin Square Building of the New England Telephone and Telegraph Company.

Buildings will be erected at the seven relay points, to house transmitting and



Map showing sites for proposed A. T. & T. microwave relay stations

receiving apparatus. At each station, highly directive antenna systems will pick up and amplify the radio waves and beam them on a direct line-of-sight path to the next station.

Field work on the project this year is expected to include building roadways up the hillsides to the relay stations, and preparing for connections with power and telephone lines.

The New York-Boston experiments are planned in three parts of the radio frequency spectrum—near 2,000, 4,000 and 12,000 megacycles. Eight channel assignments, each 20 mc wide, are being requested from the FCC in each of these parts of the spectrum. It is planned to use the eight channels to provide two simultaneous transmissions in each direction, with different frequencies in adjacent relay sections.

If the experimental facilities prove as satisfactory as the radio engineers expect, and if this method of transmission is found to be economically feasible, apparatus will be standardized in order that the Bell System may be prepared to install similar systems on other routes throughout the country as the need develops. The same set of frequencies can be used over and over at alternate relay stations on these systems. In cases where two or more systems radiate from one terminal or where branch circuits connect with the backbone network, additional frequency assignments may be necessary. The probable later addition of spur connections to nearby cities and towns points to a spreading out of radio relay channels in all directions from a backbone network. It is entirely possible that the radio relay systems eventually will be connected with the Bell System's coaxial cable network for nation-wide telephone service and for sound and television program transmission.

The New York-Boston route was selected for the experimental trial of microwave radio relay because of its nearness to the Bell Telephone Laboratories in New York and because of the continuing need for additional facilities between these two cities. Also, with coaxial cable already in place between New York and Washington, completion of the radio relay system would provide very broad band transmission facilities all the way from Boston to Washington.

It is expected that at the completion of the experiments the facilities will be available for commercial use. At that time applications will be filed wth the FCC for commercial licenses.

The radio research and development personnel of Bell Telephone Laboratories is now engaged almost entirely on war work. The New York-Boston project will be carried forward as rapidly as personnel may be released from this work.

HUNDRED MILLION RADIOS FORECAST FOR POSTWAR

American families will buy 100,000,000 radios within the first five or six years after total victory, with two-thirds of the current population ordering the first new sets on the market—preferably combination radio-phonograph models. More people say they will pay an additional $75 for television than will spend $10 extra for FM but if FM doesn't dig a hole in their pockets any deeper than $5 they say they want it almost to a man; demand as many gadgets as they can get, insist on short wave although they seldom use it on their present sets.

[*Continued on next page*]

THIS MONTH

These were a few of the features of postwar buying forecast through a nationwide survey of home radio owners, announced here today by Frank Mansfield, Director of Sales Research, Sylvania Electric Products Inc.

Conducted by one of the country's leading independent market research organizations, the study presents an accurate, unbiased picture of the nation's prewar radio buying habits and gives a cue to postwar expectations. For a period of over four months interviewers traveled to homes of all economic groups in large cities, small cities, country homes and farms from Maine to California in order to secure a fair cross section of American opinion and Sylvania's sponsorship of the survey was not even known by the interviewers.

Current Buying Habits

They found some surprising facts concerning general buying habits. Contrary to the popular American custom of looking over merchandise in a dozen stores before making a selection, Mr. and Mrs. John Q. buy their radios in the first shop they visit two times out of three.

The 31,000,000 radio homes in the country now have an average of 1:54 sets per home and, according to Mr. Mansfield, not only is there a steady increase in the number of people owning a radio but an equal growth in the number of families owning two or more sets is indicated. Mr. Mansfield predicts that when radios go into mass production again the average will rise to two sets per home.

In the past, radio buyers displayed little loyalty to the brand of radio already owned. Illustrating this, sixty-three per cent of the families who own three sets admitted that all three were different brands.

While the average set is turned over every seven years, half the radios now in operation are between four and eleven years old and their owners have little to say against them. Only five per cent expressed any real dissatisfaction.

Mr. Mansfield, who presented a question-by-question analysis of survey results, declared that every figure in the tabulation holds considerable significance. Explaining the forecast of 100,000,000 radio sets in the homes of 194X, he said, "Thirty-six million families now populate the United States and our survey shows that over 83% have home radios, totalling approximately fifty million sets. Once the war is over, the number of families will increase at the rate of a million a year for the following five or six years. Returning veterans will marry and set up new homes while others, already married but living with their parents, will set up housekeeping for themselves. All of them will want radios. Add to this the steady increase in home radio ownership apparent before the war, and the average turnover rate of seven years. Simple arithmetic gives the seemingly startling total of 100,000,000 radios including automobile sets."

FM Future

Frequency Modulation will be a big selling factor, with over ninety per cent of the people looking forward to it. A small group would be willing to pay $30 extra for FM, half of those interviewed would pay an additional $10, but the majority of listeners would prefer to pay only about $5 for the clearer reception possible with FM.

Television Potential

Provided that telecasting stations are within range, and program quality is acceptable, the public think they will buy fifteen million television sets at $75 over the usual cost of a radio set. Mr. Mansfield pointed out however, that this group may be disappointed. "It looks as if good television reception", he said, "will cost anywhere from $125 to $200 extra. But it is entirely possible, that within a few years after introduction on a large scale, television will be low enough to meet majority acceptance. Survey results show that at present only a little over three per cent of the people will pay $300 and under thirty per cent want to see television programs if it adds $125 to $200 to the cost of the set." "Remember though," he warned, "this is only a reflection of what people *think* they want."

Short Wave Factor

Home radio owners are divided almost equally among those who have short wave facilities and those who do not. "Even those who have short wave and don't use it will want it on their new sets," declared Mr. Mansfield. "They won't use it any more than they do now, but they'll want it to be there just in case to show to their friends." At present only about 5% of the U. S. radio families listen to short wave programs regularly.

Push Button

Push button tuning is fairly popular. Of the 31% that have it, three-quarters like it, the rest report unsatisfactory service, which indicates, according to Sylvania, a need for considerable improvment on this type of tuning.

Asked what they like about their sets, owners had this to say, in the order mentioned: Tone and reception is good on over 75% of the sets, half the owners are pleased with the models and styles, like the tuning, get good distant reception, get good volume, little static. "This represents an average of over two favorable comments for each person answering and speaks well for the radio industry", said the Sylvania spokesman. "Even when urged to think of complaints only 47% could think of anything at all wrong with their present radios."

Immediate Customers

As soon as radios become available, over twenty million families will buy new ones. Over 46% say they want Radio-phono models, the majority preferring console styles. Analyzing these figures, Mr. Mansfield declared that they show a trend toward one basic model for each home and additional small sets in other rooms—kitchen, bedroom, playground and the like.

First ten of the brands now in use rate in the following order are, according to survey figures: Philco, RCA, Zenith, Emerson, Silvertone, General Electric, Crosley, Majestic, Air Line, Stewart Warner.

"Answers to this survey," said Mr. Mansfield, "give our industry an excellent clue to what the public wants in radio, and an opportunity to provide greater radio enjoyment through better equipment designed to fit those requests."

Personal Mention

Lieutenant Commander Ralph T. Brengle, U. S. Naval Reserve, of 411 Battery Lane, Bethesda, Maryland and 605 W. Washington Blvd., Chicago, Illinois, is shown receiving the Secretary of Navy commendation ribbon which accompanied his letter of commendation from Vice Admiral H. Kent Hewitt, U. S. N., Commander United States Eighth Fleet.

(Official U. S. Navy photograph)

Commander Brengle, who is well known in Chicago and national radio circles, was cited for his outstanding performance of duty while serving on the staff of Commander Eighth Fleet during a period of almost continued offensive operations against the enemy in the central and western Mediterranean from October 1943 through October 1944.

Herbert Becker, for nearly three decades a radio amateur, has been appointed northern California representative for the Universal Microphone Co., Inglewood, Cal. He at one time edited "73", a ham journal in Los Angeles and was an editor of RADIO when the magazine was published on the west coast.

His headquarters will be at Burlingame, Cal. Until recently he was field engineer of Eitel-McCullough, Inc., San Bruno, Cal.

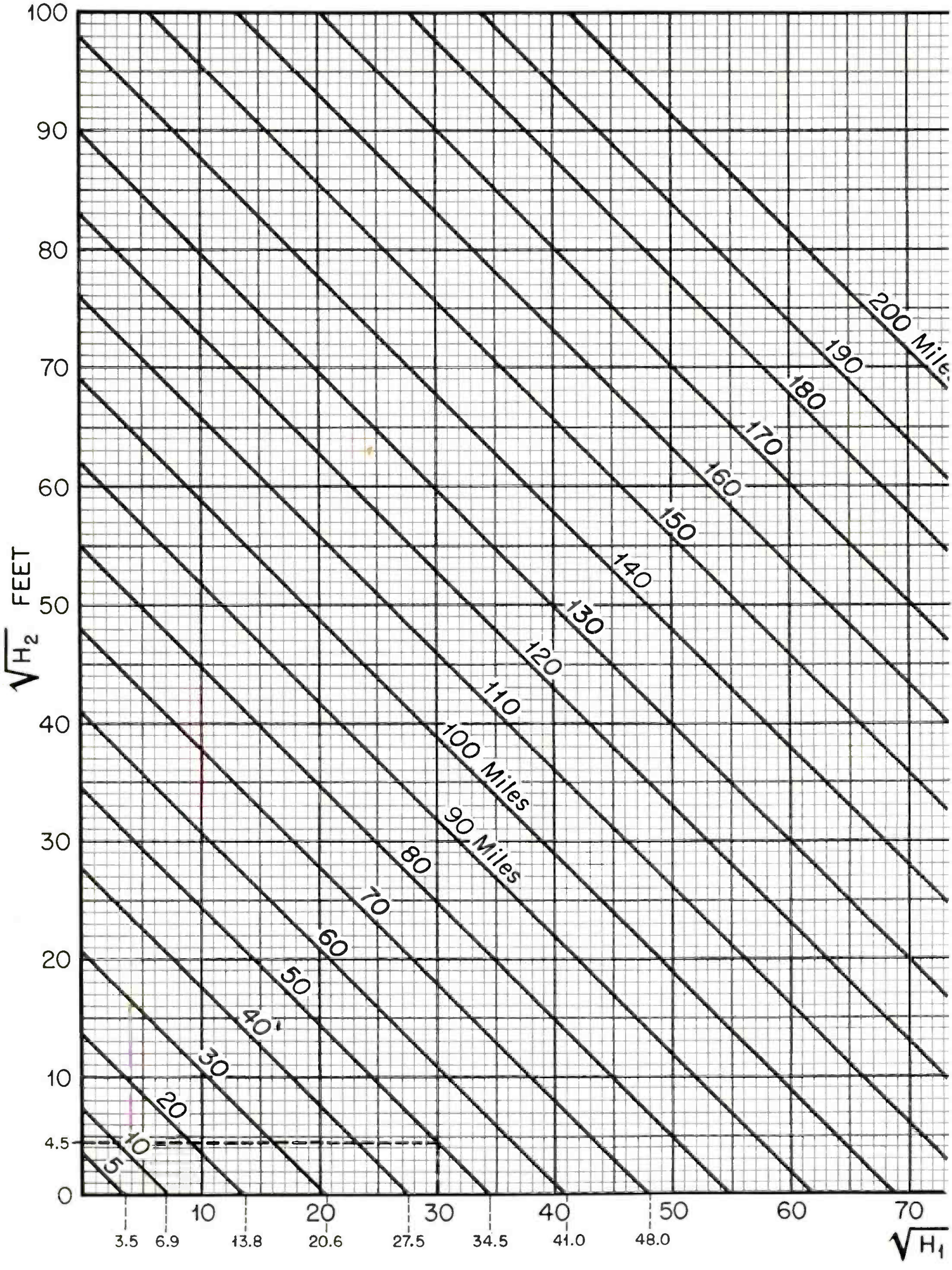
Mr. Becker is secretary of the West Coast Electronic Manufacturers' Assn., and also secretary for the San Francisco Council of the Assn.

S. H. Cohn, Los Angeles, for many years California factory representative for Universal, will now handle southern California, that is, Fresno and south.

Dr. Norman A. Skow, formerly of Bakelite Corporation, assumes his new post as Director of Research, Synthane Corpora-

[Continued on page 56

Transmission Path for Quasi-Opti

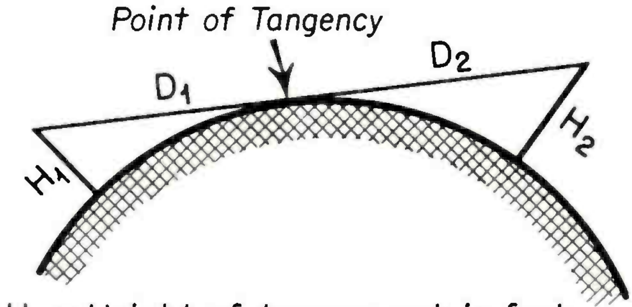


ical Waves Over Spherical Earth

$$D_1 = 1.414\sqrt{H_1}$$

$$D_2 = 1.414\sqrt{H_2}$$

$$D_1 + D_2 = 1.414\sqrt{H_1} + 1.414\sqrt{H_2}$$

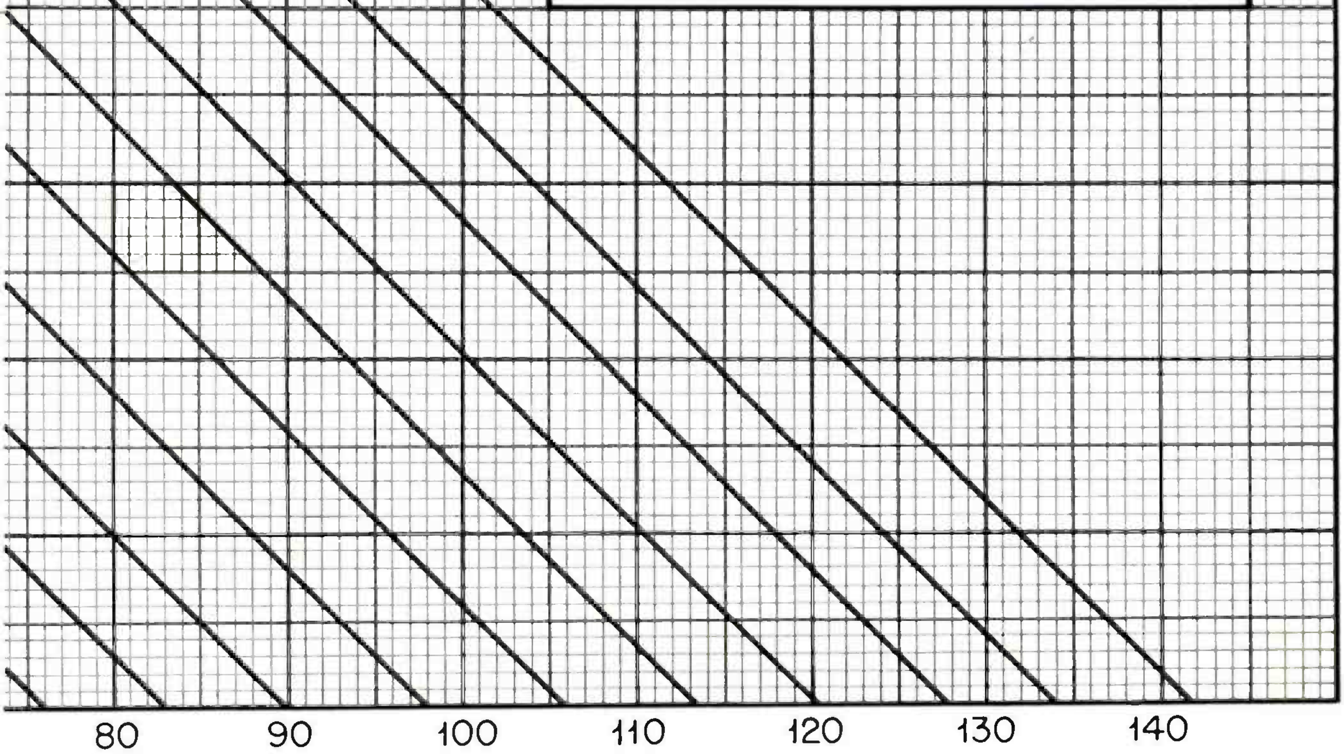


H_1 = Height of transm. ant. in feet.
H_2 = Height of receiver ant. in feet.
D_1 = Dist. point of tangency to ant. miles.
D_2 = Dist. point of tangency to ant. miles indicate length of transmission path ($D_1 + D_2$)

PROBLEM: For transm. ant. 900 ft. high, find height of receiver ant. for 50 Miles transmission path.

$\sqrt{H_1} = \sqrt{900} = 30$ which intersects 50 Mi. curve at ordinate 4.5.

$\sqrt{H_2} = 4.5$, $H_2 = (4.5)^2 = 21$ ft. height of receiver antenna.



FRANKLY, SMITHERS, YOUR DIRECTORS DON'T NEED TO SEARCH THE SCRAP PILE, ALBION CAN SHIP ALL THE COILS YOU NEED!

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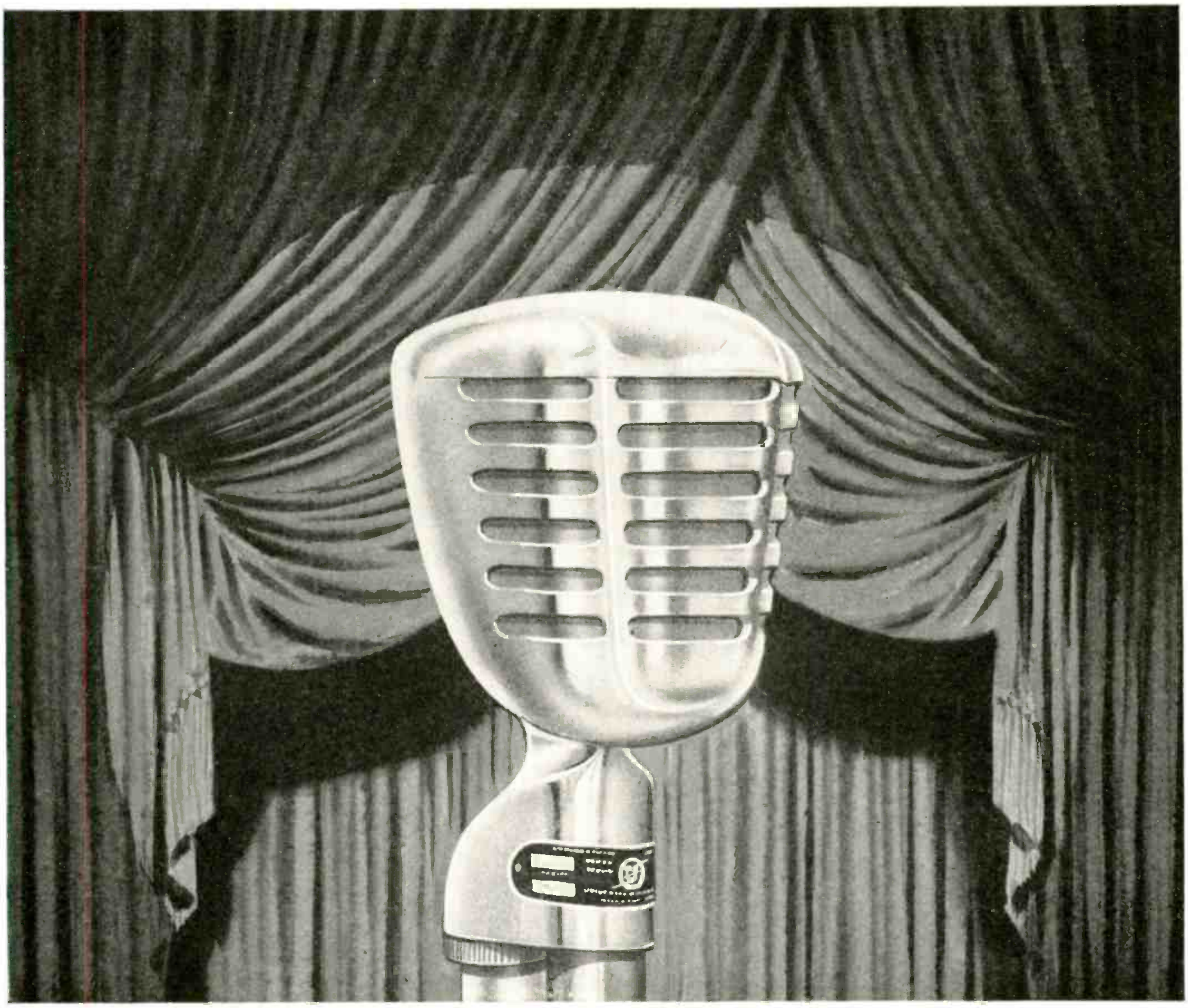

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The stage was set for something new and here it is. Universal's new D-20 Microphone . . . soon on your radio parts jobbers' shelves to fill your essential requirements . . . uses Universal's "Dynoid" construction . . . A dynamic microphone of conventional characteristics built to fill the utility requirements of war time plus advance styling of the many modern things to come. Orders placed now with your Radio Parts Jobbers will assure early delivery when priority regulations are relaxed.

Write for Bulletin 1458 covering this new microphone.

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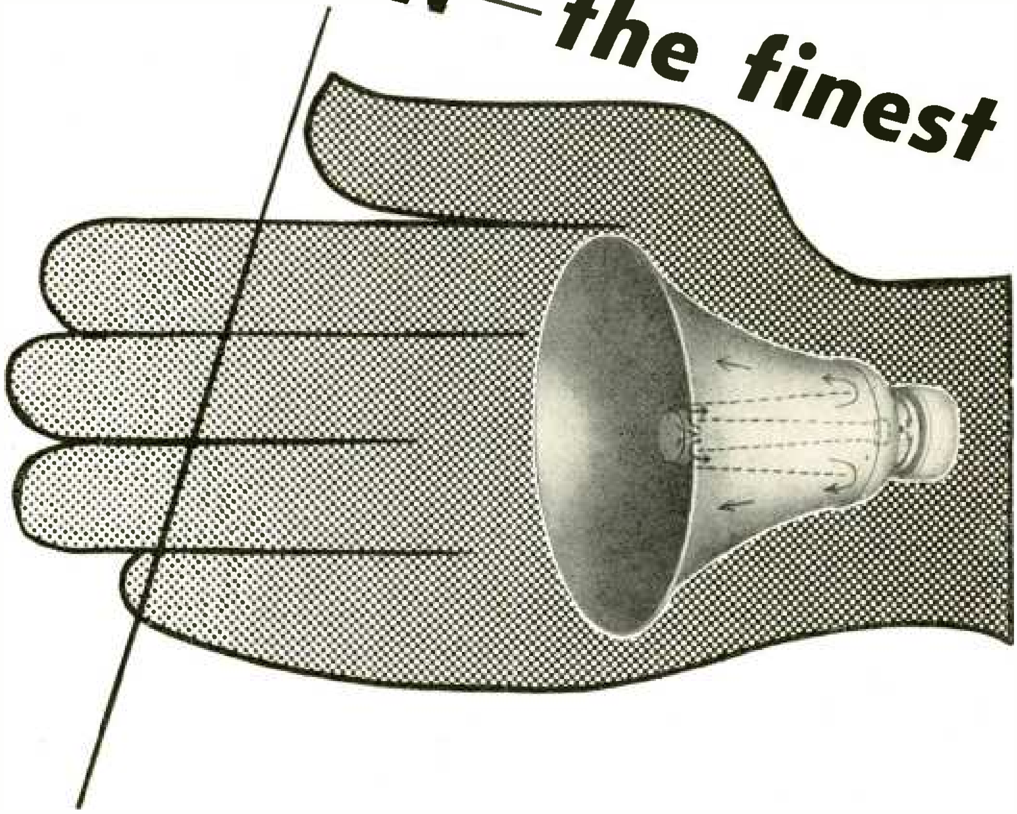

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[*To be continued*]

New Products

MYKROY IN LARGER SHEETS

The company announces the addition of new larger size sheets in its Mykroy line of perfected glass bonded mica ceramic insulation. This type of insulation is considered by engineers to be the best ever produced for all electrical and electronic applications. The largest sheet heretofore available was only 14¼" x 19¼". The new larger sheet is twice this size. Cutting efficiency shows a greater percentage increase than increase in plate area over previous sizes. Also reduction in the amount of scrap per sheet results in considerable saving—as high as 33 1/3% in usable material depending upon the size of the work piece. For the first time bar stock in rounds and squares is available to 29¼" in length and ⅛" to 1¼" in diameter or cross section which are very desirable for inductance coil construction.

The new sheets are made in thicknesses ranging from ⅛" to 1½". Because of the greatly increased size it is now possible to use this perfected high frequency insulation for:

1. Switchboard panels
2. Large inductance bars
3. Insulated Table Tops
4. Large Meter Panels
5. Transformer Covers
6. Switch Connecting Rods
7. Bases for Radio Frequency or Electrical Equipment assemblies and structural members in R-F equipment where low-loss insulation is indispensable.

All fabricators of glass-bonded mica materials should seriously consider the use of these larger plates to reduce the costs and the amount of time required in filling their orders. They are ready for immediate delivery and most thicknesses are carried in stock.

An eight page Bulletin #102 contains technical data on sheet and bar material and is available upon request.

FEDERAL VOLTAGE REGULATED POWER SUPPLY

A compact, light-weight, many-purpose rectifier unit for use in a wide variety of applications where closely regulated direct-current is required has recently been announced by the Federal Telephone and Radio Corporation of Newark, New Jersey.

This Federal Power Supply, which has been designated FTR-3128-S, has been primarily designed for use in aircraft manufacture and maintenance, for testing instruments, inverters, controls, and radio navigational and communications equipment. At the same time it can be used in numerous other applications where an easily portable, well-regulated d-c power supply is required.

The unit utilizes the Federal Selenium Rectifier and operates from a single phase a-c input of 115 volts, 58 to 62 cycles, providing d-c power up to 10 amperes, continuous duty, at any selected voltage between 22 and 30 volts.

Output voltage is automatically held constant within + or — 0.5 volt regardless of load variation from zero to 10 amperes, or a-c line voltage fluctuations of 105 to 125 volts. Ripple voltage is limited to approximately 5%.

In addition, a new and outstanding feature is the ability of this unit to maintain its performance with line frequency changes which exceed those of commercial power lines.

An on-off switch, 0-30 scale d-c voltmeter, and d-c output terminals are mounted on the front panel. An 8 foot rubber-covered cord with metal sheathed plug is provided for a-c input connection. The entire equipment, which weighs approximately 74 pounds, is enclosed in a black medium-wrinkle finish cabinet, 11¼" x 8" x 16".

CAPACITORS

*Vitamin Q, a special oil-impregnant pioneered and perfected by the Sprague Electric Company, North Adams, Mass., has resulted in capacitor developments of far-reaching importance for high-temperature, high-voltage applications. Moreover, when used on jobs where high temperature is not a factor, these capacitors result in materially higher ratings for a given size.

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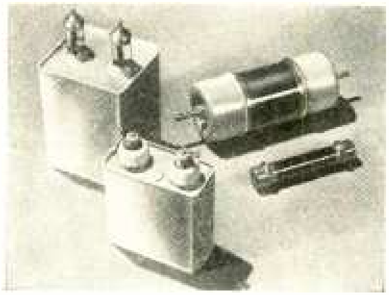


Although extremely compact, Sprague Type 25P capacitors utilizing the Vitamin Q impregnant, operate satisfactorily at thousands of volts at ambient temperatures as high as 105° C. Leakage resistance at room temperature is 20,000 megohms microfarad, or at least five times higher than that of previous types.

Sprague Vitamin Q impregnated capacitors retain all of the virtues of conventional oil-impregnated units throughout the extreme range of +105°C. to —40°C. Standard types include hermetically sealed rectangular metal container capacitors in styles for 95°C. and 105°C. continuous operation, and in d-c rated voltages from 1,000 to 16,000 volts. Other types include Type 45P hermetically sealed in glass shells with metal end caps. Complete details will gladly be sent on request to the manufacturer.

SIGNAL INDICATOR

A continuously, self-testing, small-size, shock resistant, three-way signal indicator called the "Teller", produced by Dietz Mfg. Co., 2310 South La Cienega Boulevard, Los Angeles, Calif., has been engineered to overcome the disadvantages found in mechanical signals and signal lamps.

Simple construction; no filament to burn out, no springs or levers to give trouble.

Weight installed, .64 ounces; voltage, 18-39 d.c.; wattage, 1.2; temperature, minus 75 degrees to plus 160 degrees F.; altitude, to 50,000 feet.

Typical applications: antenna reel, bomb release, battery cart, landing gear position, oxygen warning, fuel pressure, signal-call, fire warning, beacon indicator, radio and radar.

CATHODE RAY TUBE BOOK

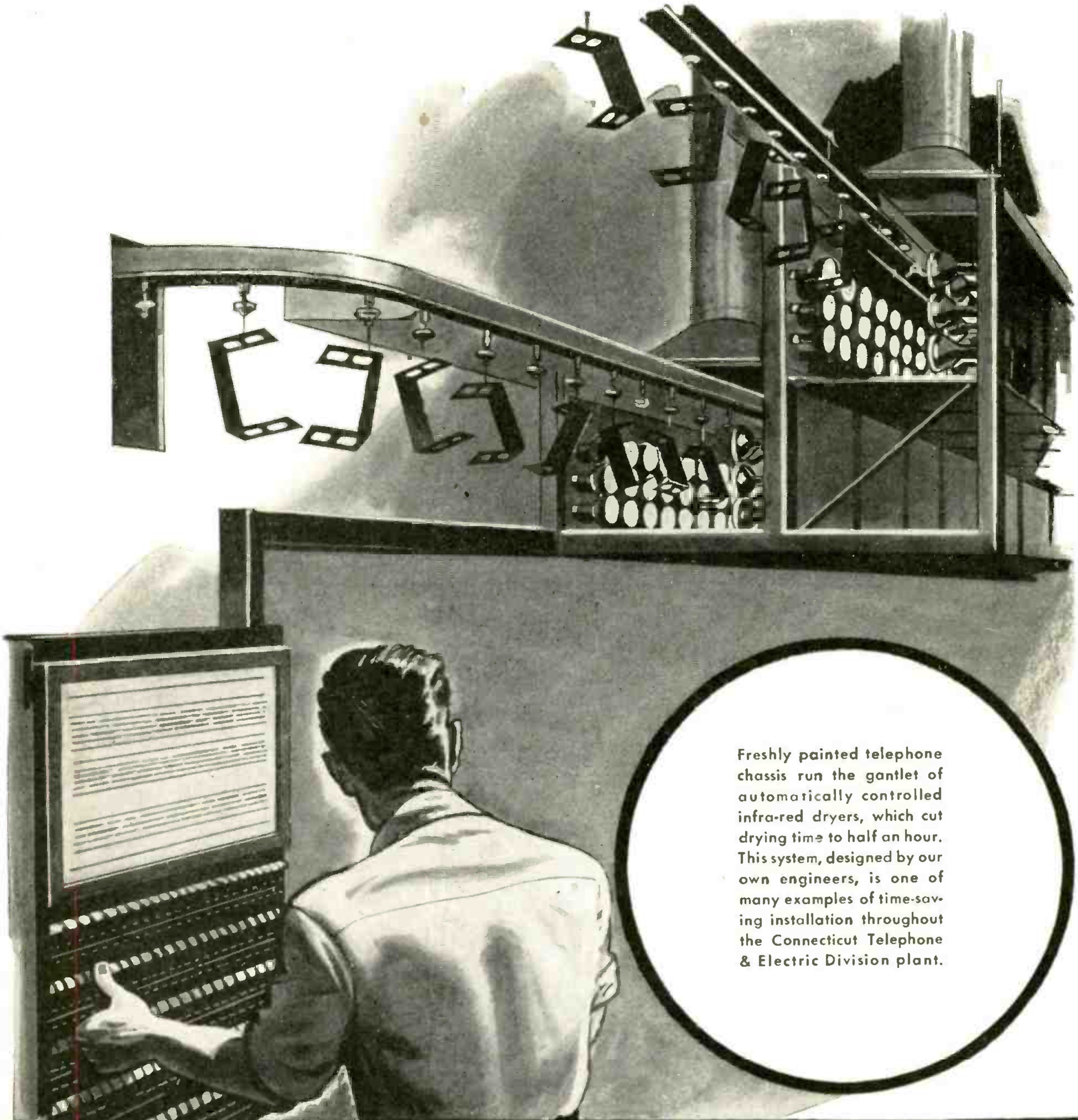
A new 16-page illustrated booklet on "How & Why Cathode Ray Tubes Work" including a discussion of complete television set-ups, has been announced by North American Philips Company, Inc., 100 East 42nd Street, New York. This

"DO NOT SQUANDER TIME"

. . . Benjamin Franklin

At Connecticut Telephone and Electric Division, production is unhurried, as it must be to maintain accuracy and quality in precision electrical and electronic manufacturing. We substitute *time-saving* methods for *hustle and bustle*. This has enabled us to keep abreast of the ever-increasing need for military communicating equipment of uniform dependability.

After the war, you will very likely use electrical equipment, electronic devices, or communicating systems made at Connecticut Telephone and Electric Division . . . Or you may be one of the many manufacturers who will use our engineering and manufacturing facilities in connection with your own products . . . In either case, our time-saving methods will be your gain, measured by the important standards of uniform high precision, and speed of filling your orders.



Freshly painted telephone chassis run the gantlet of automatically controlled infra-red dryers, which cut drying time to half an hour. This system, designed by our own engineers, is one of many examples of time-saving installation throughout the Connecticut Telephone & Electric Division plant.

CONNECTICUT TELEPHONE & ELECTRIC DIVISION

GREAT AMERICAN INDUSTRIES, INC. • MERIDEN, CONNECTICUT company is one of the leading producers of this type of tube.

The text material was written by J. R. Beers, Development Engineer, and is divided into four sections.

Early history, mathematical concepts present-day problems, are treated in *Section 1*. Schematic diagrams help to convey the idea of how the tube functions. The subject of screens and their characteristics is treated at some length.

Section 2 takes up C-R tube manufacturing problems. Curves and pictorial illustartions are used to describe materials, assembly and visual inspection.

Testing of C-R tubes is the subject matter of *Section 3*. Many photos of screen patterns help to identify the wide variety of defects that are enumerated.

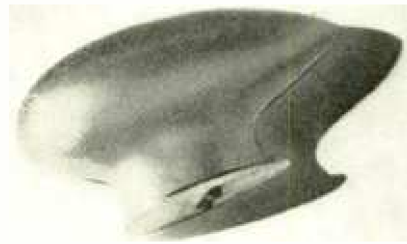
Section 4 goes into special C-R tube designs. Here complete television set-ups are shown and discussed along with lens systems, color filters and three-color screens.

NEW DIRECTION FINDER

Development of what is stated to be the first radio direction finder in which no a-c supply from the aircraft is needed, has been announced by the Fairchild Camera & Instrument Corporation, New York.

The new compass is a four-band instrument, is 28 per cent smaller in size and 21 per cent reduced in weight over the old Fairchild three-band model, thousands of which are in use in military and commercial planes.

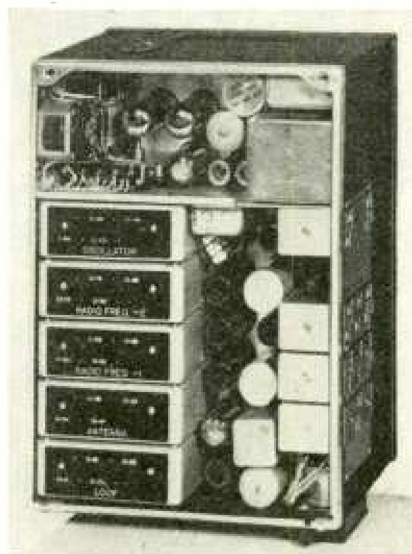
Only the regular aircraft storage battery supply of 28 volts d-c is required for the new model, rather than the 100-to-



Stream-lined loop housing

250-volt plate currents which are standard in other equipment. A-C voltages for the indicators and the loop drive motor are formed by means of a small vibrator and the 28-volt d-c supply, and reception continues if the a-c voltages fail; then the loop can be turned manually and there is aural indication of the course.

There are both strategic and scientific reasons for the addition of a fourth band in the compass. Fairchild's former model, the SCR-269, provided the 200-410, 410-850, and 850-1750 kc bands. The new development has the 100-200 kc band frequency, too.



Compact d-f design

The strategic reason is to take radio navigational aid from the many European and Asiatic stations which broadcast in the 100-200 KC field. The scientific reason is that at night there is less scattering and shifting in the path of these frequencies between a radio station and a remotely located aircraft, thus providing superior night navigational properties.

The new smaller and lighter equipment makes automatic radio compass navigation available for smaller aircraft, such as long-range fighters.

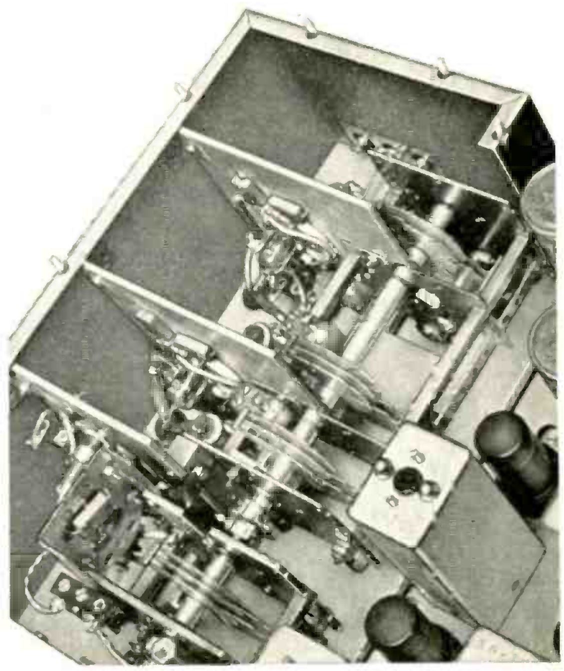
The Fairchild instrument was developed in co-operation with the War Department and was tested at Wright Field under supervision of the aircraft radio laboratory, communications and navigation section.

HOW hallicrafters EQUIPMENT COVERS THE SPECTRUM

Model S-37
FM-AM
for very high frequency work
130 to 210 Mc.

THE new Model S-37 FM-AM receiver is an outstanding example of Hallicrafters pioneering work in the upper regions of the spectrum. Covering the frequencies between 130 and 210 megacycles, the S-37 provides VHF performance which is in every way comparable to that of the finest communications receivers operating in the medium and high frequency bands. The average over-all sensitivity of the S-37 is approximately 5 microvolts. The image ratio of at least 1000 times is achieved through the use of two pre-selector stages and an intermediate frequency of 16 megacycles. No band switching is necessary and exceptional ease of tuning is provided by mechanical band-spread with 2300 dial divisions between 130 and 210 megacycles. The pre-loaded gear train is completely enclosed and is equipped with a positive stop at each end of the tuning range. Hermetically sealed transformers and capacitors, moisture proof wiring, and extra heavy plating, all contribute to the long life and reliability of the S-37 . . . the only commercially built receiver covering this frequency range.

The amazing performance of the Model S-37 is largely due to the RF section shown at right. It is mounted as a unit on a brass plate 1/4 inch thick. The two type 954 RF amplifiers and the type 954 mixer are placed in the heavy shields which separate the stages. The type 955 oscillator is mounted directly on its tuning condenser. Exceptional stability is assured by the use of individually selected enclosed ball bearings, extra-heavy end plates, and wide spacing in the oscillator condenser – rigid mounting of all components – and inductances of 1/8 inch copper tubing wound on polystyrene forms. All conducting parts are heavily silver plated.



Write for Catalog No. 36E, describing Hallicrafters complete line of high frequency receivers and transmitters.

BUY A WAR BOND TODAY!

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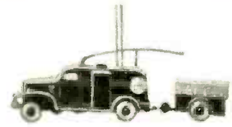


THE HALLICRAFTERS CO., MANUFACTURERS OF RADIO AND ELECTRONIC EQUIPMENT, CHICAGO 16, U.S.A.

THIS MONTH

[*Continued from page* 40]

tion, Oaks, Pa. A native of Iowa, Dr. Skow received his B.S., M.S. and Ch.E. at the University of Iowa and his Ph.D. at Cornell University. He is a member of Sigma XI, Alpha Chi Sigma, the American Chemical Society, the American Institute of Chemical Engineering and the Society of Rheology.

Dr. Skow will devote his energies to research and development of Synthane plastics for technical applications.

Rex L. Munger, formerly Sales Manager of Taylor Tubes, Inc., has been appointed Middle West representative for Communication Measurements Laboratory, 120 Greenwich Street, New York City, N. Y. to dispose of surplus radio and electronic materials of all types for the Defense Supplies Corporation, a Government agency. He will represent CML in Pittsburg and Ohio, Kentucky, Indiana, Michigan, Illinois, Wisconsin, Minnesota, Iowa, Missouri, Kansas, Nebraska, the Dakotas, Wyoming and Colorado.

Surpluses will be sold to manufacturers and distributors in accordance with the plans of the Government not unduly to disturb the radio industry and to prevent wholesale dumping which might upset the balance between supply and demand or the labor picture.

In addition Munger will also represent CML in their regular line of test equipment for manufacturers.

Simultaneously with this work, Munger will continue to act as Advisory Sales Manager to Taylor Tubes where he will make his headquarters at 2312 Wabansia Ave., Chicago, Illinois.

The Hallicrafters Company's "unqualified approval" of proposed frequency allocations above 25 megacycles was read into the records of the Federal Communications Commission by Cyrus T. Read, director of sales engineering for the firm, at the opening day of hearings (Feb. 28) in Washington on the Commission's postwar allocation plan.

According to Read, the statement citing the position of the Hallicrafters Company was based on the opinion of its engineering department and carried the approval of William J. Halligan, president.

Praising the foresighted action of the Commission in proposing to establish FM broadcasting on frequencies where it will be free from interference and will have room to become a truly adequate service, Read said it was the opinion of the firm's engineers that such a service cannot be permanently established in the present band of 42 to 50 megacycles.

He pictured the "degradation which the FM service is sure to encounter in its present position due to long distance sky-wave interference" as of great importance from the standpoint of public welfare.

"With the present small number of transmitters in operation this problem is not serious," he explained," but as the band becomes more fully occupied it is sure to be a major source of annoyance to listeners."

UTC APPOINTMENTS

Under the major expansion program at the United Transformer Corporation, 150 Varick St., New York 13, N. Y., Samuel L. Baraf has taken over the merchandising activities as Director of Sales and Merchandising.

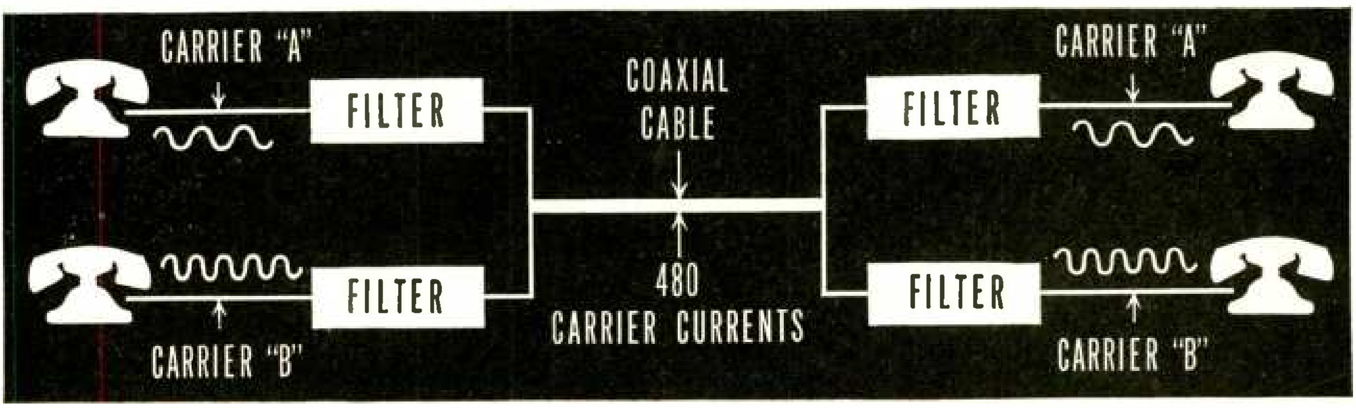
Simultaneously, Ben Miller joined UTC and occupies the post of General Sales Manager.

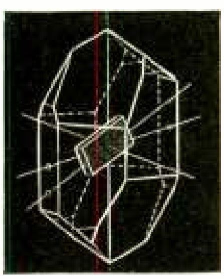
S. L. Baraf and B. Miller

Mr. Baraf, who will have complete charge of surveying present-day and potential industrial markets and planning for large scale distribution, stated:

"In line with our expanded industrial program which calls for a re-evaluation and a thorough analysis of present and potential markets, we needed an overall Sales and Merchandising Director. That job has been wished onto me, effective immediately! And we are fortunate to

Crystal gateways for your voice





Four hundred and eighty telephone conversations over a coaxial cable was one of the last peacetime achievements of communication research in Bell Telephone Laboratories. In this multi-channel telephone system, each conversation is transported by its own high-frequency carrier current. At each end of the line are crystal gateways; each opens in response to its own particular "carrier" with the message it transports. In telephone terminology, these gateways are filters.

The ultra-selective characteristic of these filters is made possible by piezo-electric quartz plates, cut in a special manner from the mother crystal, and mounted in vacuum. Each set of plates is precisely adjusted so that the filter responds only to the frequency of its assigned channel, rejecting all others. In the coaxial terminal equipment, such crystal gates sort out messages for delivery to their four hundred and eighty individual destinations.

In recent years, Bell Telephone Laboratories research has provided the Armed Forces with many types of electrical equipment in which frequency is controlled by quartz crystals. Notable is the tank radio set which enables a tank crew to communicate over any one of 80 different transmission frequency channels by simply plugging in the appropriate crystal. The future holds rich possibilities for the use of quartz crystals in Bell System telephone service.

BELL TELEPHONE LABORATORIES

Exploring and inventing, devising and perfecting for our Armed Forces at war and for continued improvements and economies in telephone service.

THIS MONTH

[*Continued from page* 56]

have Ben Miller join us as our new General Sales Manager, a post he is well prepared to handle."

Ben Miller served as Purchasing Agent at Wholesale Radio Co. in New York, from 1930 to 1941. He then joined the Meissner Manufacturing Corp., of Mt. Carmel, Ill., as Sales Manager. In 1943, Ben Miller opened his own office and became a Sales Representative in the Chicago area.

Samuel L. Baraf and I. Allen Mitchell are the founders and owners of the UTC organization, which has made so many basic innovations in the transformer field.

Announcements will be forthcoming from time to time, as plans now under development are completed.

Hytron Changes Name

At a meeting of the Board of Directors on March 2, the name of Hytron Corporation, Salem, Mass., was changed to Hytron Radio and Electronics Corporation.

The following officers were elected: Bruce A. Coffin, President and General Manager; Lloyd H. Coffin, Treasurer and Chairman of the Board of Directors; Edgar M. Batchelder, Executive Vice President; Charles F. Stromeyer, Vice President and Director of Engineering.

MICRO TOPICS

Micro Topics, house organ of the Universal Microphone Co., Inglewood, Cal., after two years of publication as a bi-weekly, on April 1 changed to a monthly publication and circulation will now go outside the Universal organization.

An engineering section for sound men has been added. It will contain data supplied by a technical committee including James L. Fouch, president; Les Willyard, chief engineer, and Jack Hall, production manager.

I. R. E. BUILDING

On grounds that engineers will add sight to sound in radio broadcasting after the far, hundreds of broadcasters, coast-to-coast, were asked today to lend financial support to the campaign being conducted by the Institute of Radio Engineers to raise $500,000 for a headquarters building in New York City.

In letters addressed to every broadcast station, ranging from the little 100-watter to those rated at 50 kilowatts of power, J. R. Poppele of Station WOR, chairman of the Broadcasting Division of the society's building fund campaign, wrote an engineering formula by which they might measure their technological stake in the future. "If the projection of the leading lady's glamour into the homes of postwar America is to include the dancing of her eyes and the shimmer of her gown in addition to the lilt of her voice," said Poppele, "it will be done by some pretty matter-of-fact scientists and engineers. These men will work far behind the microphone and televisor, designing studios, broadcasting stations and home receivers. They deserve industrial and public support in perfecting their society's service in keeping them informed of latest laboratory developments here and abroad."

The Institute, with more than 13,000 members, is the world's foremost electronic engineering association. Dr. W. R. G. Baker, General Electric's Vice-President, Bridgeport, Conn., heads its Initial Gifts Committee, and Powel Crosley, Jr. President, The Crosley Corporation, Cincinnati, is honorary campaign chairman. Serving with Poppele in the Broadcasting Division are the following industry leaders: William B. Lodge, Columbia Broadcasting System, and O. B. Hanson of National Broadcasting Co., New York; R. Morris Pierce of Station WGAR, Cleveland; Paul F. Godley, Montclair, N. J.; R. J. Rockwell, Station WLW, Cincinnati; Irving Robinson, Yankee Network, Boston; C. R. Evans, Station KSL, Salt Lake City; and Frank M. Kennedy, Don Lee Broadcasting System, Los Angeles.

INSULATION MANUAL

The Mica Insulator Company, 200 Varick Street, New York 14, New York, announces the publication of an 86-page illustrated manual on electrical insulating materials made and marketed by the Company. The manual includes data, tables and values on sheet mica, built-up mica, laminated plastics, varnished cloth and tapes as well as miscellaneous insulating materials such as varnishes, twines and fiberglas.

Copy of the manual will be sent on request upon company letterhead.

T IS FOR "TROPICALIZED"

. . . . which means that STANDARD Sprague Koolohms now have the same EXTRA HUMIDITY PROTECTION formerly obtainable only on special order.

WOUND WITH CERAMIC INSULATED WIRE

DOUBLY PROTECTED by glazed CERAMIC SHELLS and NEW TYPE END SEALS

All Sprague Koolohm Resistors are now supplied with glazed ceramic shells and a *new type of end seal* as standard construction.

These features provide maximum protection against the most severe tropical humidity and corrosive conditions. Extensive tests in the laboratories of the armed forces and prime contractors have proven the ability of the "KT" construction to "take it" under the most brutal air thermal shock, humidity, and corrosive conditions.

Type "KT" Koolohms correspond to characteristic "J" of resistor specification JAN-R-26.

All previous catalog designations remain the same except for the addition of the letter "T" to the old type numbers to designate the new standard construction.

Thus "T" is for "Tropicalized"—and all Sprague Koolohms have it. One type of Koolohm, the *standard* type, does the job—under any climatic condition, anywhere in the world.

SPRAGUE ELECTRIC CO., Resistor Division, North Adams, Mass.
(Formerly Sprague Specialties Co.)

ARMY E NAVY

SPRAGUE
KOOLOHM RESISTORS

TRADEMARK REG. U. S. PAT. OFF.

RECEIVER DESIGN

[*Continued from page 33*]

realized if alternate transformers are single peaked (critical coupled) to such a degree that the overall characteristic is flat. Single stage and overall selectivity curves are shown in *Fig. 8.* The valley in the center of the over coupled stage is compensated by the peak of the critically coupled stage and as long as the required transmission band is essentially flat no distortion will be evident.

CONVERTER-OSCILLATOR STAGE

The converter stage may consist of one or two tubes according to the price bracket for which the receiver is being designed, if an r-f stage will be employed, or for performance reasons.

Most FM receivers include an r-f stage and it is practical to employ some type of combination converter-oscillator tube. Since the operation of the converter stage is the same for either AM or FM signals it is not felt necessary to discuss the subject in detail. A few observations however will not be out of order. For instance, when tubes other than the pentagrid or similar types are employed, the method of oscillator voltage injection to the mixer must be decided.

In the past, many UHF receivers have depended on mutual industion between the r-f and oscillator coils for proper mixing. Although the conversion gain with this type of injection is satisfactory, considerable interaction will be noticed between circuits and it will be very difficult to properly align the receiver. This trouble can be eliminated by using the second harmonic of the oscillator instead of the fundamental to produce the i-f beat frequency. R-f and oscillator circuits will then have very little interaction and operating the oscillator at half its normal frequency results in greater oscillator stability. Mutual inductive coupling is not particularly desirable since the spacing between coils must be held quite accurately and lead dress is often extremely critical. It is therefore much better to employ cathode injection or electron coupling within the tube. In this way circuits can be made substantially independent or one another and greater stability will result.

R-F AND ANTENNA STAGES

The first detector sensitivity should be approximately 45 microvolts to give the proper input voltage to the limiter stage. We will then require a combined r-f and antenna stage gain of at least 45 to provide a one microvolt sensitivity. It would be possible under ideal conditions to obtain this amplification in the r-f stage alone when using a high transconductance tube. These conditions unfortunately do not exist in a receiver built

[*Continued on page 62*]

TRANSMISSION LINES

[*Continued from page 28*]

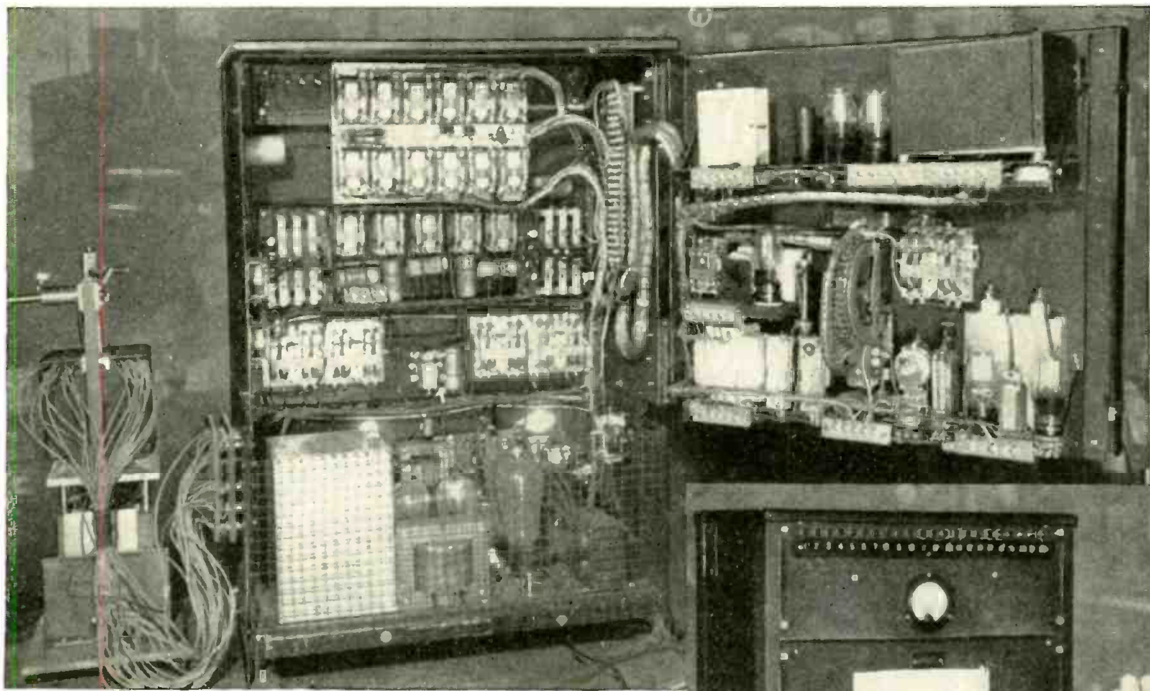
at a later time is more difficult than it is to remember the traveling wave idea and know that the whole pattern will move toward the source.

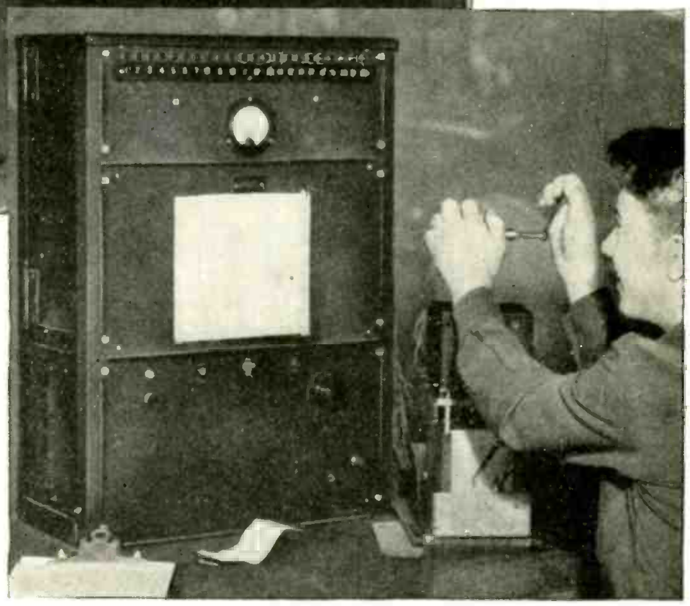
Now if the line is not infinite nor matched to a load, the pattern of *Fig. 4* will suffer reflections and the actual voltages in the line will be made up of sets of traveling waves moving in both directions and each looking like what has been sketched. If actual measurements are made on such a line composite values are obtained but from these it is not too hard to deduce the strength of the wave moving in each direction. From that information can then be obtained data on the degree of the impedance match and the efficiency of the transmission.

Radiation Limitations

In general, it may be stated that the amount of radiation which must be tolerated from a parallel wire transmission line depends upon the separation of the wires. If the wires can be kept closely enough together, the radiation can be kept very small. In *Fig. 5* are shown the magnetic fields that exist around two isolated wires which are respectively carrying current toward and away from the reader. It is clear that if these lines were very close together these fields would come very close to canceling each other and, to the extent that they did cancel, there could be no radiation since both electric and magnetic fields are necessary in order that energy move on out into space. It is certainly impossible to carry this to the limit because at least insulation must be placed between the conductors. Also it may be noted that as the wires are brought very close together the distributed capacity of the line is increased, which is a possible situation for audio frequencies but not one to be tolerated for uhf.

In any event for one reason or another it is certainly necessary to maintain a minimum spacing between the wires for proper insulation and impedance properties. This requisite space is not made smaller by going to shorter wave lengths and higher frequencies and yet the radiation fields which depend upon rate of change becomes much more important. Because of this it is impossible to build satisfactory parallel wire transmission lines for operation at frequencies much in excess of 200 megacycles.





Rear view of new **FOSTER** "ROBOT" TESTING APPARATUS. Open panel reveals complex electrical units.

Front view of "ROBOT." Controls are few and easy to operate. High-precision readings visible at a glance.

FOSTER AUTOMATIC "ROBOT" ELIMINATES HUMAN ELEMENT IN TRANSFORMER INSPECTION

This is the new Foster "Robot"—an ingenious Foster development designed to eliminate fallible human judgment in the final test and inspection of Foster transformers.

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Designed to meet the heavy demands of Foster's wartime commitments, the new Foster "Robot" will continue as an integral part of Foster testing equipment after the war. It is one more assurance that your peacetime Foster transformers will maintain the highest possible standard of performance. And, because it is a time-saver, the "Robot", together with Foster's other streamlined techniques, will actually save you money.

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by production methods. Tolerances in tube and component parts will be instrumental in reducing the gain of some receivers to approximately half this value. These tolerances in addition to general circuit losses such as tuning condenser wiper leads, coil and condenser insulation, by-pass condenser leads, socket insulation, etc., will account for an additional reduction in gain.

A gain of 15 in the r-f stage is about the limit for good stability. Even this amount of gain will require the use of high-grade components and careful chassis layout. Coupling between tuning condenser sections and common impedance in the ground leads must be minimized, otherwise regeneration will exist which will result in an unsymmetrical selectivity curve.

Another point to be considered in the design of an r-f stage is the image response. This varies approximately inversely with the Q of the coil so it is evident every effort should be made to maintain as high a Q as possible. But in an effort to increase the Q by increasing the inductance, it is important that the minimum circuit capacity is not reduced to such an extent that variations in tubes affect the circuit alignment to any appreciable degree.

The antenna stage gain (transformer) depends mainly on the impedance of the tuned circuit and the input impedance of the tube. The tuned circuit impedance is a function of the inductance of the coil and should be as high as possible. This requires a minimum of circuit and tube capacity. A tuned circuit impedance of the order of 12,000 ohms can be readily obtained in production units. If such a tuned circuit is fed into a tube having an infinite impedance the antenna coil gain would be approximately 10, however the input impedance of the tube at frequencies in the FM band are normally comparatively low. Since the two impedances are in parallel the net result is also low and the actual gain is only about three.

This can be increased somewhat by the use of unby-passed or partially unby-passed cathode resistors as shown in *Fig. 9*. Note that the suppressor and screen grids are connected or by-passed to ground instead of to the cathode as is the usual practice.

This completes the discussion of the various sections of the conventional FM receiver. Several other methods of FM reception have been proposed from time to time, notably among them being the frequency-dividing locked-in oscillator type receiver, as described by Beers[5], an FM receiver, using superregeneration, by Kalmus[6], and the Autosynchronized-Oscillator type of receiver by Woodyard[7].

Having covered the FM receiver as a unit we will now consider a few prob-

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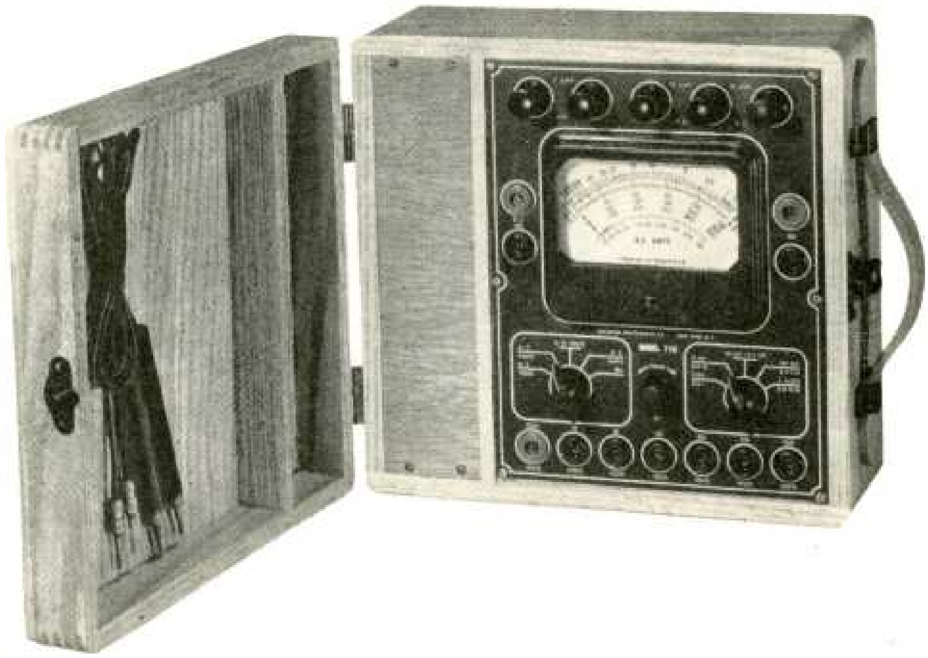

Sensitivity—

1,000 OHMS PER VOLT
ON BOTH A.C. and D.C.!!

Measures—

A.C. AND D.C. VOLTAGES UP TO—
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A.C. CURRENT UP TO—
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★ Uses New 4½" Square Rugged 0-400 Microampere Meter.
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Designed and perfected in wartime to meet the exacting requirements of America's War Producers for a dependable volt-ohm-milliammeter, the Model 710 is being used by war plants engaged in the production of planes, ships, tanks, guns, etc., also by various Army, Navy and other governmental agencies.

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6 D.C. VOLTAGE RANGES (1000 OHMS PER VOLT)
0 to 15/60/150/300/600/1500 Volts.

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0 to 15/60/150/300/600/1500 Volts.

7 D.C. CURRENT RANGES
0 to 3/15/60/150 Milliamperes   0 to 3/15/30 Amperes.

A. C. CURRENT RANGE:
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5 RESISTANCE RANGES:
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The MODEL 710 comes complete with cover, self-contained batteries, test leads and instructions. Size 6" x 10" x 10". Net weight 11 pounds. Price.................................... **$34.50**

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lems in the design of a combination AM-FM receiver.

COMBINATION AM-FM RECEIVER

The combining of FM and AM reception in a single receiver usually results in design compromises. This is due to the difference in frequency, selectivity and bandwidth requirements of the two basic services. Several possible solutions present themselves, each having their advantages and disadvantages. Some designs have employed a separate i-f amplifier for each service and while such a solution involves very few engineering problems, it is very costly and therefore impractical for large quantity production in a competitive field. A simplification of this system uses separate i-f transformers for each frequency and by switching the desired transformer into the circuit the same tubes are used for each service. This reduces the cost by saving the extra tubes, however the switching becomes a major design problem both mechanically and electrically. Unless the leads being switched are short and direct, which limits the chassis layout arrangement, stray coupling is inevitable and regeneration or oscillation is likely to result.

Probably the best solution to the problem is to combine the separate low and high frequency i-f transformers into a single unit. By connecting the tuned circuits in series as shown in *Fig. 10* it is then possible to eliminate the i-f switching between AM and FM. This appears to be a good solution to the problem since it saves using separate tubes for each i-f system and possibly will eliminate any switching. Since the FM windings are above ground potential, by the impedance of the AM windings, it is evident that the impedance of the AM circuit must be made as low as possible for the high frequency i.f. This is accomplished by taking a loss of gain in the AM section of the transformer. Fortunately the i-f gain and bandwidth required for FM reception makes the use of high transconductance tubes in the i-f amplifier a necessity and therefore the impedance of the AM circuits can be made quite low without seriously sacrificing the overall performance. Gains of 50 to 100 are still obtainable for AM because of the high transconductance tubes.

As mentioned previously, with the two i-f systems onnecected in series there is a possibility that switching can be eliminated, since the low frequency i.f. can be designed to serve as a by-pass to ground for the low potential end of the high frequency coils. But when the complete combination i-f amplifier is operating several spurious responses may be evident. Direct signal pickup on the unused i-f section might make it advisable

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Official U. S. Navy Photo

Admiral Halsey has his eye on a fine white horse called Shirayuki.

Some time ago, at a press conference, he expressed the hope that one day soon he could ride it.

The chap *now* in Shirayuki's saddle is Japan's Emperor—Hirohito.

He is the ruler of as arrogant, treacherous, and vicious a bunch of would-be despots as this earth has ever seen.

The kind of arrogance shown by Tojo—who was going to dictate peace from the White House . . . remember?

Well, it's high time we finished this whole business. High time we got the Emperor off his high horse, and gave Admiral Halsey his ride.

The best way for us at home to have a hand in this clean-up is to support the 7th War Loan.

It's the biggest loan yet. It's two loans in one. Last year, by this time, you had been asked twice to buy extra bonds.

Your personal quota is big—bigger than ever before. So big you may feel you can't afford it.

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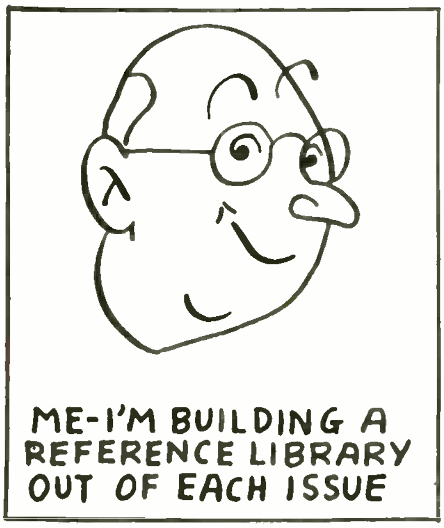

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to short out this section, at least at the converter plate where sensitivity is the greatest. An undesired FM response due to a difference frequency equal to the low frequency i-f, produced by the signal beating with the local oscillator, will also be eliminated if the first transformer is switched. In general, the use of combination i-f transformers is to be preferred because of lower cost and better physical chassis layout, even though some switching of leads is required.

References

[3] Thompson—Oscillation in Tuned R-F Amplifiers—*Proc. IRE*, March 1931

[4] Foster and Rankin—I-F Values for FM Receivers—*Proc. IRE*, October 1941

[5] Beers — Frequency-Dividing Locked-In Oscillator FM Receiver—*Proc. IRE*, December 1944

[6] Kalmus—Notes on Superregeneration for FM—*Proc. IRE*, October 1944

[7] Woodyard—Application for Autosynchronized Oscillator for FM—*Proc. IRE*, May 1937

TECHNICANA

[*Continued from page* 22]

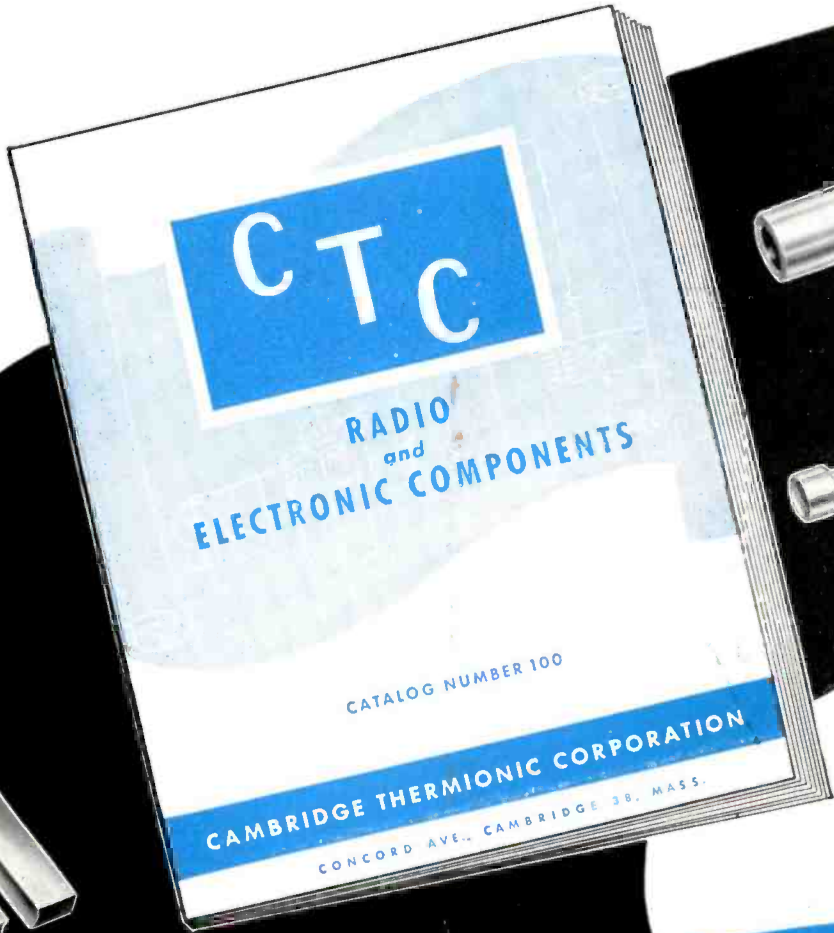
The 440 cycles per second is the standard musical pitch, A above middle C; the 4000 cycles per second is a useful standard audio frequency for laboratory measurements.

In addition there is on all carrier frequencies a pulse of 0.005-second duration which occurs at intervals of precisely one second. The pulse consists of five cycles, each of 0.001-second duration, and is heard as a faint tick when listening to the broadcast; it provides a useful standard time interval, for purposes of physical measurements, and may be used as an accurate time signal. On the 59th second of every minute the pulse is omitted.

The audio frequencies are interrupted precisely on the hour and each five minutes thereafter; after an interval of preciesly one minute they are resumed. This one-minute interval is provided in order to give the station announcement and to afford an interval for the checking of radio-frequency measurements free from the presence of the audio frequencies. The announcement is the station call letters (WWV) in telegraphic code (dots and dashes), except at the hour and half hour when a detailed announcement is given by voice.

The accuracy of all the frequencies, radio and audio, as transmitted, is better than a part in 10,000,000. Transmission effects in the medium (Doppler effect, etc.) may result at times in slight fluctuations in the audio frequencies as received; the average frequency received is however as accurate as that transmitted. The time interval marked by the pulse every second is accurate to better than 10 microseconds (=0.000 01 second). The 1-minute, 4-minute, and 5-minute intervals, synchronized with the seconds pulses and marked by the beginning or ending of the periods when the audio frequencies are off, are accurate to a part in 10,000,000.

ADVERTISING INDEX



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