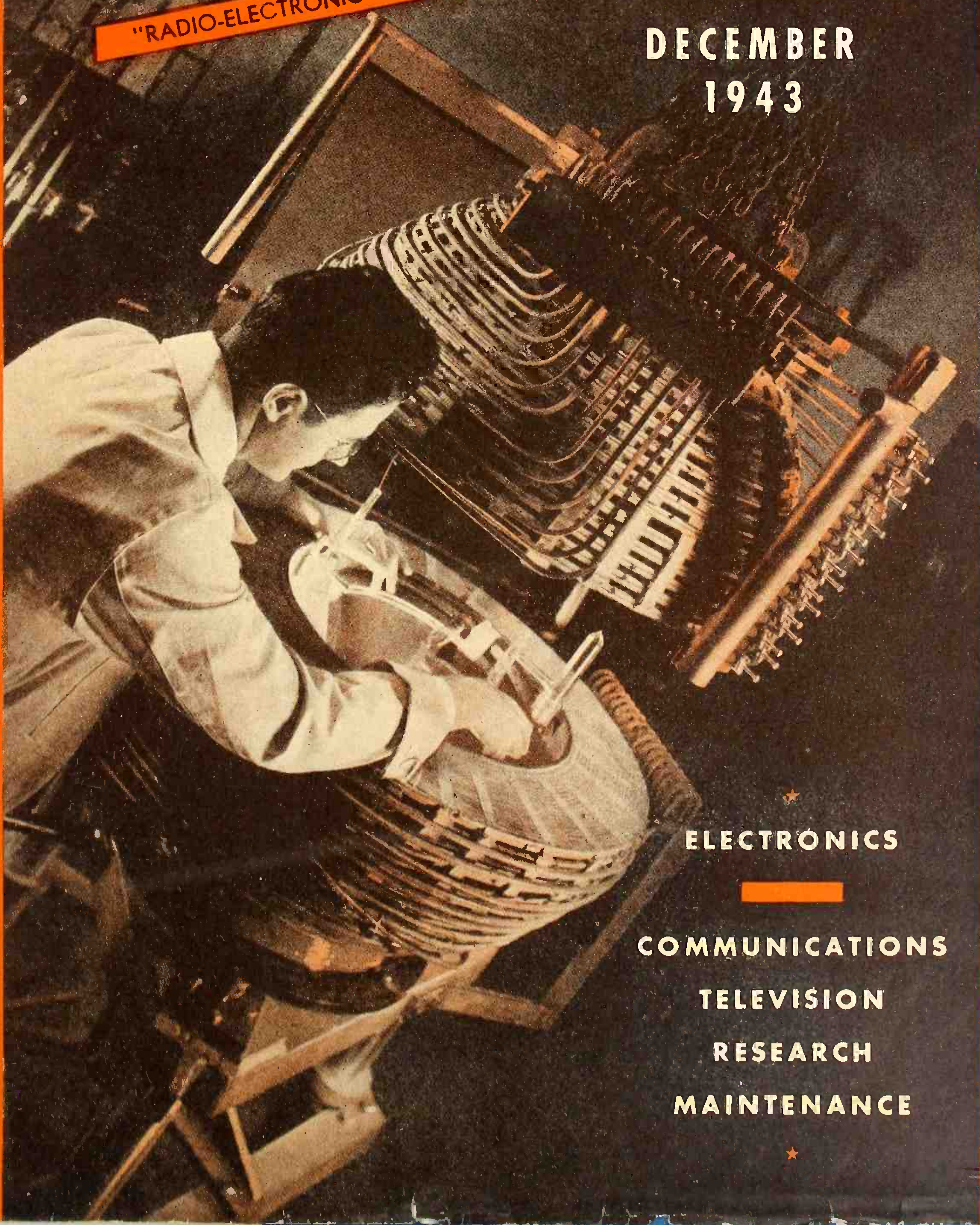
RADIO NEWS

Radionics

"RADIO-ELECTRONIC ENGINEERING"

DEPARTMENT

DECEMBER 1943



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COVER PHOTO—BY WESTINGHOUSE

"Ionic centrifuge," or mass spectrograph. This strange sorting machine segregates gas molecules and their constituent atoms according to their masses. The spectrograph will analyze a thimble full of gas, or a solid substance no larger than a grain of salt, providing it can be vaporized. The device is so sensitive it will detect one part in 100,000 of a substance under observation.

EDITORIAL

THE BASIC ENGINEERING GROUNDWORK FOR TELEVISION HAS BEEN LAID. Television, as a very substantial industry, is coming in the postwar period. The matter of supplying programs will be solved readily and quickly by American ingenuity, initiative and finance as well as by our competitive commercial system of broadcasting. It is evident that the public is ready for the new service and is convinced that television will be available on a permanent basis immediately after the war has been won and as soon as transmitters and receivers can be produced.

The expansion of the television industry depends upon the sale of television receivers to the listening public. This sale will not be affected by the motion picture, large sporting events, the theater or radio as it exists today, but in fact will actually increase due to the interest which a television program will offer.

Television must be considered as an entirely new service and not as a supplementary means of entertainment. It differs considerably from radio as a form of entertainment where twelve to twenty-four hours per day of continuous service comes from any one station. Radio is listened to many hours a day with only a small percentage of full concentration necessary.

A television program, however, will be treated as an event that will require one hundred percent attention and for that reason will be limited to only several hours a day in the average home. Once this is realized, it will be obvious that television and radio offer two distinctly different services, both of which are necessary in their appeal. There will be no competition in these services that will adversely affect the sale of either type of receiver.

Considering the competitive aspects of television and the motion picture, it is important to realize that these two services will also be distinct and different.

The most popular program items in television will be telecasts of current happenings with plenty of action. This service may be offered through the movie theater as part of its program but these items will be primarily a television service for the home.

The attendance at notable sporting events will not be substantially cut

(*Continued on page* 38)

High-Frequency Heating of PLASTICS . . .

By JOHN DALE MORRISON
Development Eng., Phoenix Metal Cap Co.

The industrial application of high-frequency heating as applied to pre-heating of plastic materials.

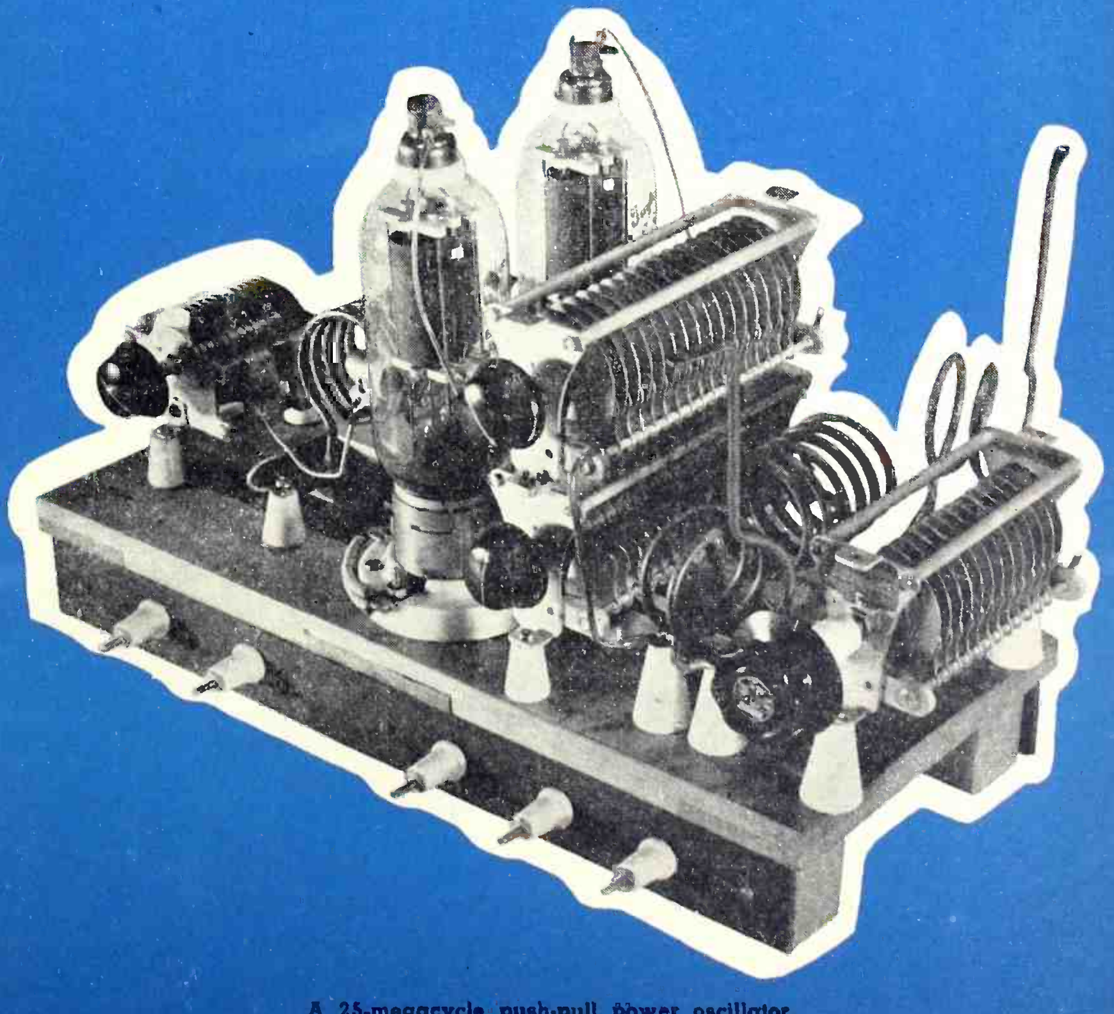
HEATING non-conductive organic materials by short waves is not new, but the method to be described in this article has not been used extensively in industrial applications.

Manufacturers of closures for glass packages had long been accustomed to the high rate of speed in producing caps from metal. When a program to produce plastic closures was initiated, the slow speed of molding plastics, even in automatic machines, presented a constant challenge. As a result of the effort to increase molding speed, a new application of electronics was developed.

Molding powder, of the thermosetting type, must have a definite time, temperature, and pressure cycle to be transformed from the powder through the plastic and finally to the cured stage. The cured stage is in the form of a solid of various shapes, depending on the dies used in the molding operation. In the particular application in mind, the caps ranged in size from 13 mm. to 38 mm. in diameter.

It is apparent that if the plastic charge, consisting of powdered plastic material, can be placed in the molding die at or near the actual temperature required for proper molding and curing, all the time required to bring the charge from room temperature to this molding temperature within the die is saved. This operation of heating the plastic charge outside of the die prior to molding is known as pre-heating.

When it is realized that a large part of the time required in a molding operation is to raise the temperature of the material to the required molding temperature, it is apparent that great time saving is gained through pre-heating, particularly in



A 25-megacycle push-pull power oscillator.

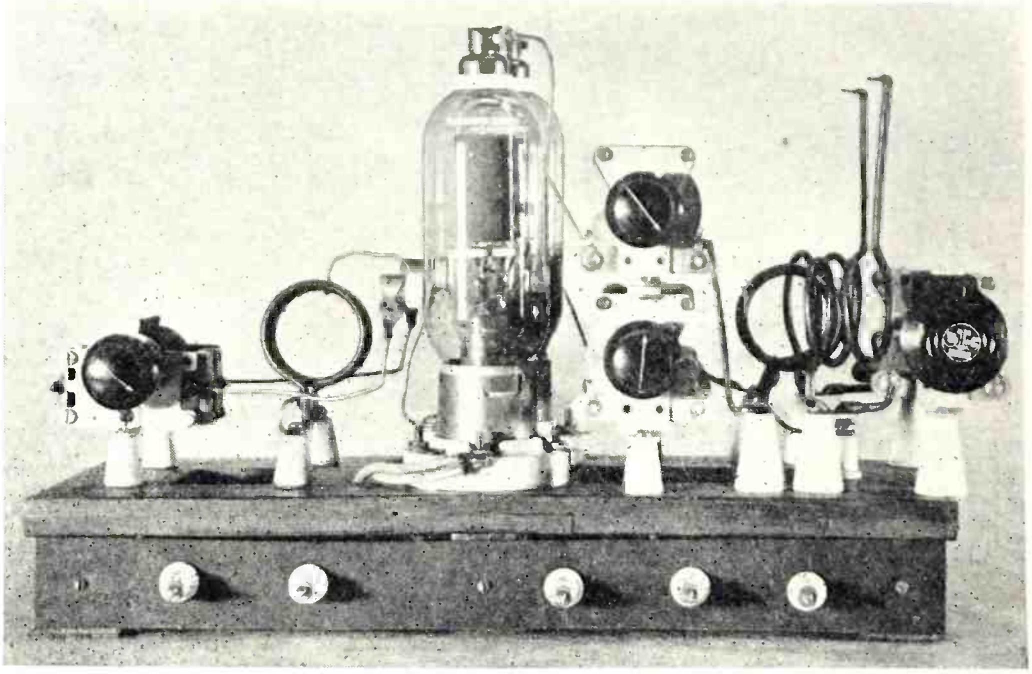


Fig. 1. Power oscillator with grid and plate tank circuits clearly shown.

automatic machines. It also follows that the closer we can approach the molding temperature in pre-heating, the higher the molding speed will be. Other gains, equally as important as increased molding speed result from pre-heating. When the powder is stored in the warehouse during the cold months, and it has absorbed excessive moisture as well as being chilled, in many instances proper molding could not be accomplished unless pre-heating was used.

If heat in the form of infra-red rays, hot air, or heated coils is used, uniform heating is not accomplished. This is due to the poor heat conductivity of the molding powder. Heat applied by these methods must penetrate from the surface throughout the depth of the material. Such methods are slow and non-uniform heating results, the surface being over-heated and the center material being underheated. The only practical method of producing rapid uniform heat in such an application was found to be by means of short waves.

If one plate of a two-plate condenser is alternately charged positively and negatively, at a high frequency, and the material between the plates is non-conductive, the molecules tend to orient themselves so that the positive end of the molecule is attracted to the negatively charged electrode and the negative end of the molecule is attracted to the positively charged electrode. As the charged plates change their polarity due to the high frequency alternations, the molecules have a tendency to change their positions with great rapidity. Because of this molecular friction, heat is produced. Since all of the molecules in the dielectric tend to move at the same time, uniform heat is produced throughout the entire volume of plastic material.

The amount of heat to be developed in the material determines the power and the frequency required. The rate of heating of a non-conducting material, such as a molding plastic in an electric field, as described above, varies as the dielectric constant of the material, the frequency of oscillations and the r. f. voltage maintained across the dielectric.

In one particular case, some means was needed to pre-heat the molding powder that flows continuously from a hopper to an automatic molding machine. A pyrex glass tube was placed between the molding material hopper and feed tube, which directs the powder into the dies. Around the outside of this tubing were two copper electrodes (Fig. 3a), spaced to avoid high frequency arcing. These electrodes ran through a rubber end piece and were connected to the "short wave generator" by a short transmission line, as shown in Fig. 3b. Around the electrodes, a pyrex glass tube was placed. This was used as a protection from r. f. voltage.

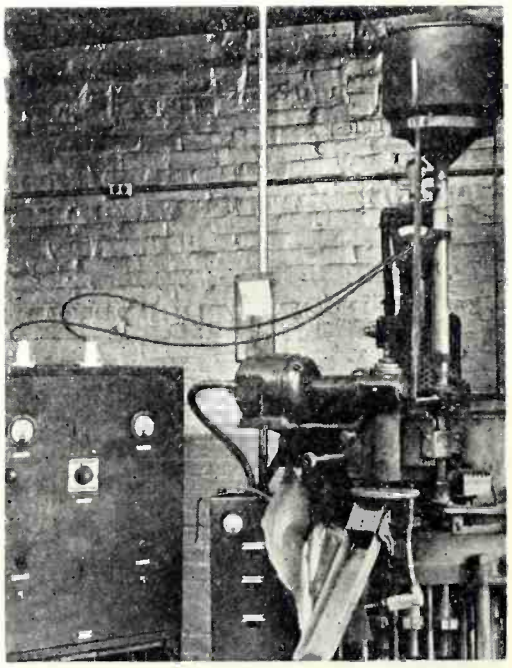


Fig. 2. Plastic molding machine equipped with high-frequency heating unit.

The gains made in production by this pre-heating method on powder have varied with the size of cap, being greater in the larger size caps, and often increasing molding speed as high as 60%.

The amount of heat that can be safely used when pre-heating powder is limited by the moisture content of the powder condensing in the feed tube. When this happens, the powder becomes damp and impairs the flow. It has been found that heating the powder between the electrodes to about 160° F. is the maximum temperature to insure proper flow.

Greater gains are made if the powder is formed into pellets or preforms, and then pre-heated. For a 28 mm. closure, the preform is shaped into a sphere about ⅝" diameter. The preforms can be heated to a semiplastic state, around 250° F. or higher. It is through the use of preforms that the maximum benefits of pre-heating can be achieved, for in this form the material can be pre-heated practically to molding temperature and still be fed at high speed into the dies of the automatic molding machine. Under this condition, the molding operation is practically reduced to forming and setting the already plastic material, and the possible production speeds are limited only by the characteristics of the material and the mechanical design of the machine.

The laboratory test unit developed was a Hartley oscillator using two Taylor T-40 tubes in parallel with 1000 volts on the plate. The success of this unit warranted building a higher power oscillator to be used in production. This was a push-pull, tuned-plate, tuned-grid, self-excited oscillator using Taylor T-200 tubes with 2000 volts of filtered rectified current on the plates. The unit is shown in Fig. 1 and the circuit diagram in Fig. 4.

This unit was operated at an average frequency of 25 megacycles (about 12 meters), which was found to be most suitable for this type of work, but is adjustable to compensate for certain material variations as described later.

Parasitic oscillations are generally encountered in new circuit designs, necessitating the proper placement of circuit components and leads. These oscillations use power, thereby reducing the efficiency of the oscillator. One difficulty that arose in a preliminary test was the cracking of the glass where the filament was molded in the transmitter tube. Filament bypass condensers did not help. This

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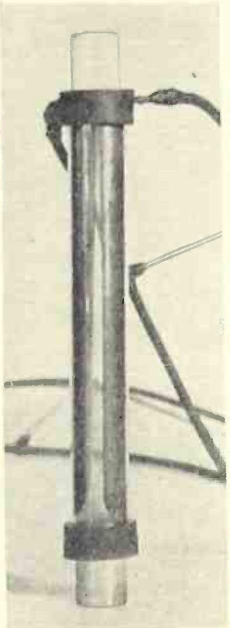


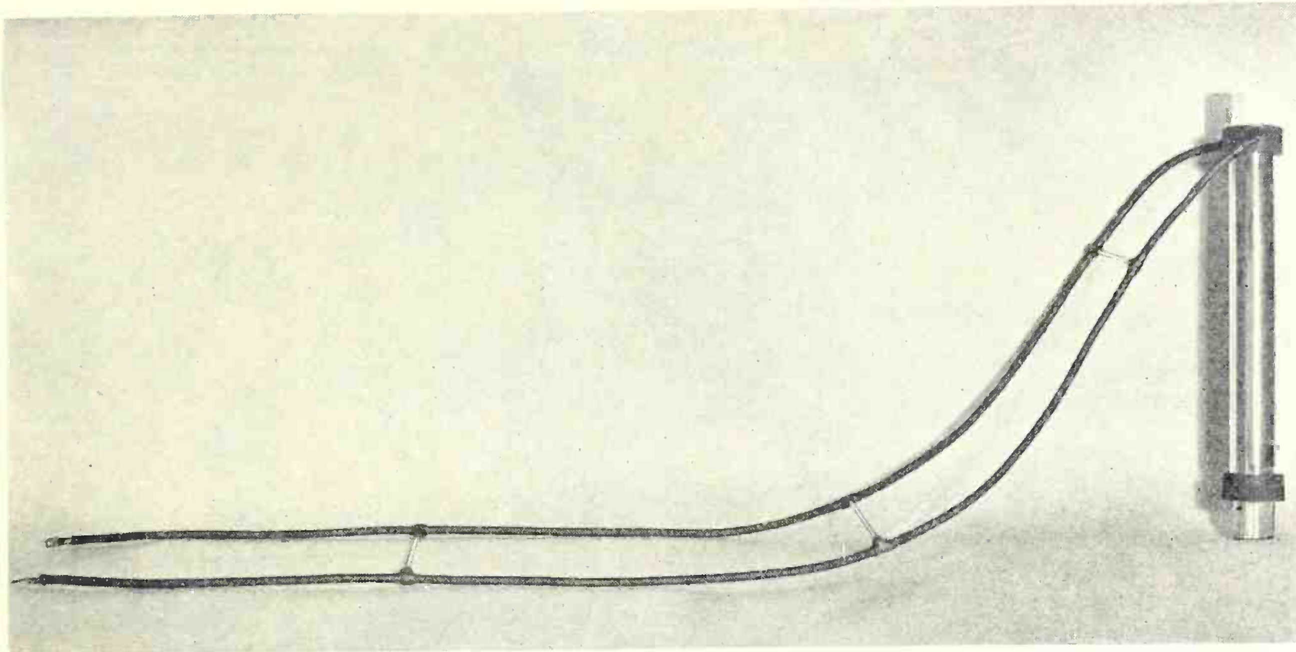
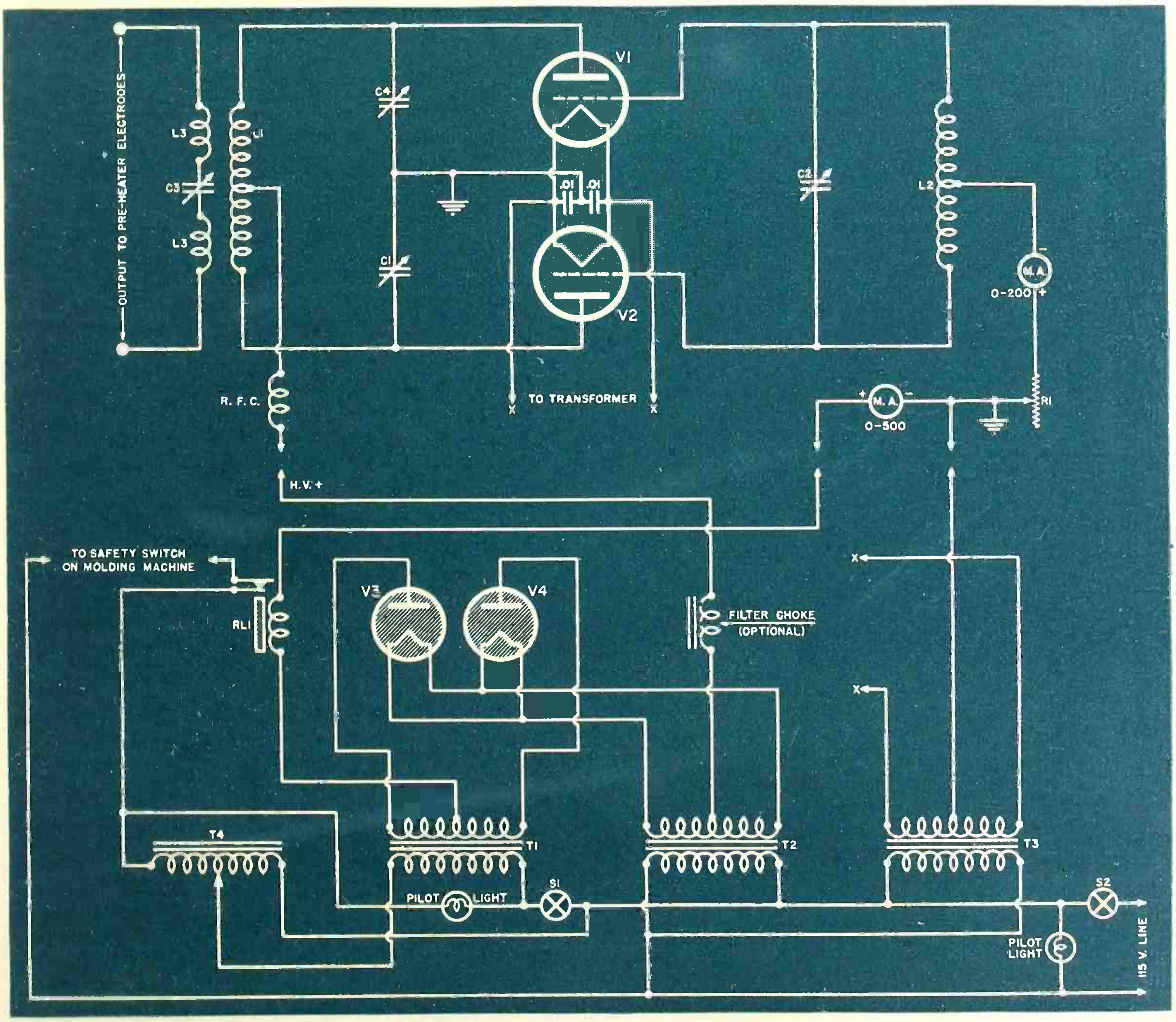


Fig. 3A (Left). Pyrex concentric tubes supporting two copper electrodes forming the capacitance of the tuned output circuit. Fig. 3B (Right). Copper electrode unit showing the transmission line.

Fig. 4. Diagram of push-pull power oscillator using T-200 tubes, and high-voltage power supply using T-866 tubes.



R_1—2500 ohm 160 watt rheostat
C_1, C_3, C_4—Variable cond., 105 μμfds, Bud JC-1542
C_2—Variable cond., 50 μμfds.
L_1—2" Diam. coil; 6 turns, winding length 3½"
L_2—2" diam. coil 5½ turns, winding length 3¼"
L_3—Two coils; each, 2" diam.; 3½ turns, winding length 2"
R.F.C.—½" diam., 50 turns #30 d.s.c. wire
RL_1—Over-load relay 40 ma. Guardian L-500
T_1—Plate transformer, Thordarson T15P17
T_2—Fil. transformer, Thordarson T19F87
T_3—Fil. transformer, Thordarson T19F90
T_4—500 watt variable voltage transformer
S_1, S_2—SPST toggle switch
V_1, V_2—T-200 Taylor tube
V_3, V_4—T-866 Taylor tube

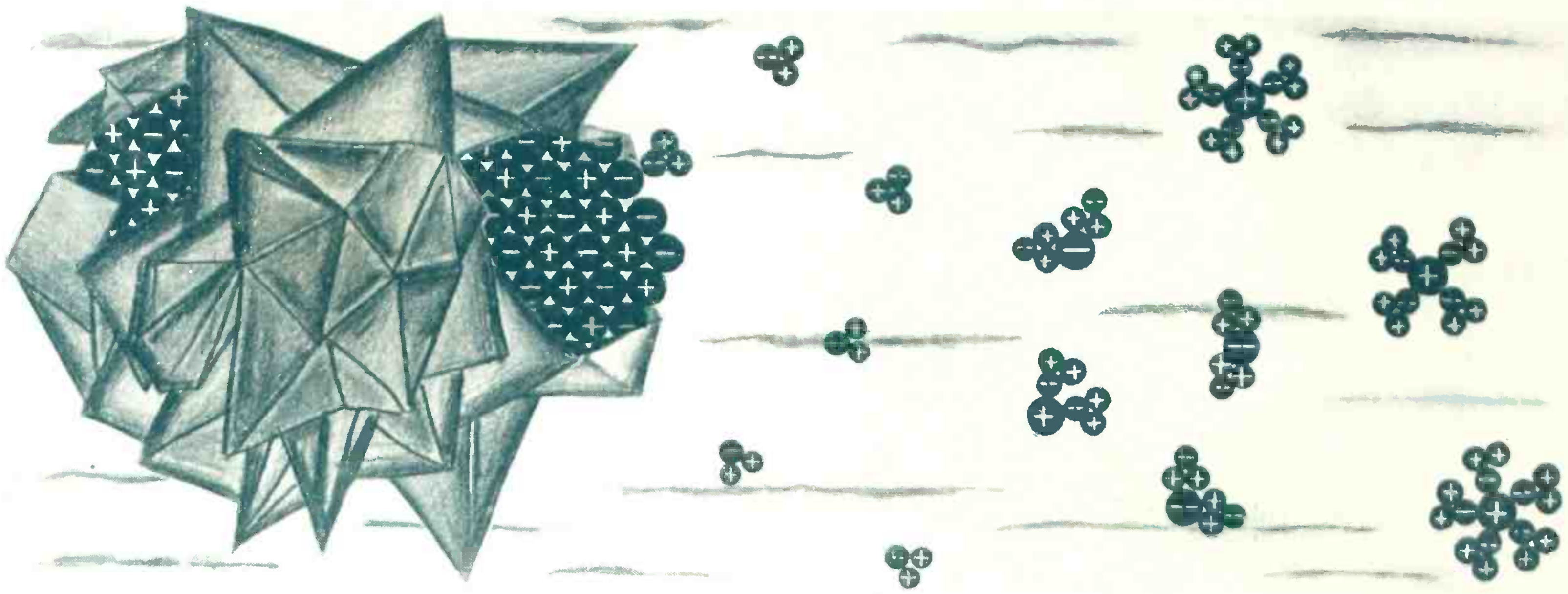


Fig. 1. Illustrating the process that occurs when crystals are being dissolved in water.

Dust—Dipoles—Dielectrics

By JOHN D. GOODELL and CAREY P. McCORD, M.D.

Applying the electro-dynamic theory and the electron microscope, to analyze the electrical and geometrical properties of minute particles and to exploit the electrically predictable properties of the mineral "Tripoli."

DUST is a ubiquitous form of matter. It appears in the sky, on the earth and beneath the sea, and plays an important part in various aspects of everyone's life. The expression "Dull as dust . . ." conveys a faulty implication. The story of a dust particle is often more exciting than anything encountered in even the most imaginative fiction. Wind and storm, a forest fire, the core of an erupting volcano, even interstellar space may have been connected with its recent history. Particles of salt from the sea; fragments of soil from Africa, Europe or Asia; silica, carbon, magnesia, iron oxide, organic tissue, pollen, aluminum silicate—all these and many more varieties of dust may be in the air that is breathed as this line is read. Dust may have as many origins as there are substances, and the possible combinations form an infinite series.

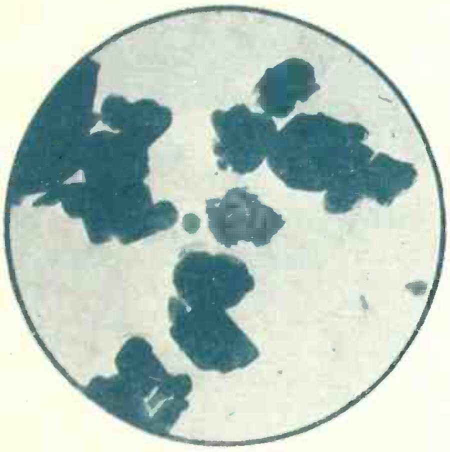
The dust form of a material exhibits properties sufficiently unique as to suggest logically that it should be added to the series—solid, liquid, gas, vapor. The peculiar characteristics associated with dust are primarily attributable to the enormously increased surface area which results when materials are divided into minute particles. Some realization of this may be obtained by considering a 12-inch cube. If it is divided into one-inch cubes, the total surface area is expanded from six square feet to 72 square feet. Dust screened to 200 mesh size approximates 0.1 mm., and if the particles are highly porous, as in tripoli (which is discussed later in this paper), one pound of the dust presents a surface area far greater than the 6,000 square feet which is usual for the commoner geometric shapes. Since it is only the surface of the material which may react with surrounding media, it is obvious that the rate of reaction is proportional to the surface area per unit volume. Explosions are caused by the increased rate of combustion when fine particles of certain substances are dispersed in the air. There is a distinct hazard to health where concentrations of dangerous dust types are high. Although the kinds of disease so caused are small in number, they loom large in frequency and severity. In recent years silicosis has become well known, even to the general public, as a serious industrial hazard.

The radionic arts have contributed considerably to an understanding of the characteristics that are associated with fine particles. Chemistry, physics, medicine and all the sciences depend increasingly upon radionics, not only for instruments to assist in laboratory work, but for a fundamental understanding of the structure that underlies all material things.

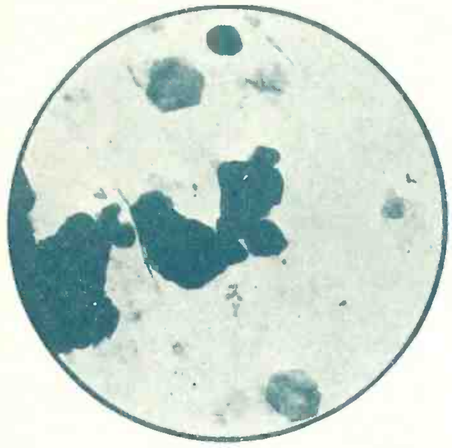
An extensive understanding of the chemical and physical structure of dust has been gained in this century, and a great deal of empiric knowledge has resulted from laboratory manipulation. The viewpoints presented here are concerned with certain far less well known electrical relationships which are the fundamental source of observed effects, and with the curious electrical phenomena coincident with high specific surface areas.

The length of this paper does not permit mathematical treatment of the inter-molecular and atomic structures under consideration, and certain premises must be accepted. The relativistic viewpoint of electro-dynamic theory and the concepts of quantum mechanics are assumed.

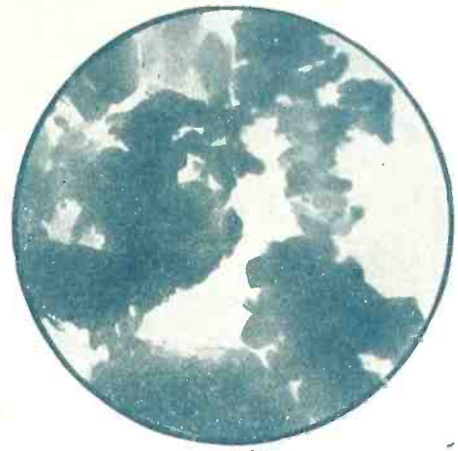
For purposes of review and coherence of reasoning, background information of generally accepted validity is presented throughout. Fundamental theory with respect to the basic structure of all the components that make up the universe is undergoing constant change. Thus it be-



(A)



(B)

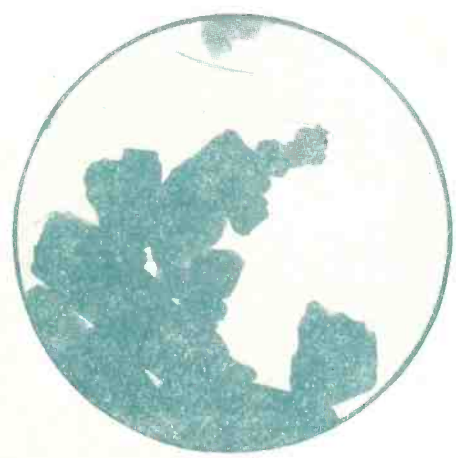


(C)

ELECTRON MICROGRAPHS ILLUSTRATING CRYSTALLOGRAPHIC PROPERTIES OF "TRIPOLI," WITH A MAGNIFICATION OF 24,000 TIMES.

(A), (B), and (C) show different views of the Missouri cream Tripoli, less than 325 mesh. (D) and (E) show two views of the Tennessee beige Tripoli, less than 325 mesh. (F) a drawing of Tripoli particles magnified 60,000 diameters.

(D)



(E)

(F)

comes necessary to define certain elementary forms in the process of conveying intelligence with words.

Free charges may be defined as simplex or complex charged structures that are capable of motion through a material when it is influenced by an impressed field. Charges not free to move under the influence of impressed fields may exist as permanent or induced electric dipoles. A permanent electric dipole consists of two charge structures of opposite sign, the centers of which are a fixed distance apart. Induced electric dipoles consist of two charges of opposite sign with centers that separate under the stress of an impressed field and coincide under relaxation. The moment of a dipole is the product of the charge and the distance between the electrical centers. In some cases the moment of a permanent dipole may increase in the presence of an electric field, giving it dual qualities. When a charge appears on the surface or in the interior of a substance resulting from the orientation of permanent dipoles or the creation of induced dipoles, it is referred to as a polarization charge. The characteristics of dielectrics result from the effects of electric dipoles.

The calculation of polarization in a medium is the vector sum of the dipole moments in a specific volume divided by the volume. Normally permanent dipoles are orientated at random and the mean electric moment per unit volume is zero. Considering the dimensions of molecules as approaching 10^{-8} centimeters and the fundamental electric charge as 4.77x 10^{-10} esu, it is evident that specific molecular dipole moments are in the order of 10^{-18} esu.

In order to avoid semantic confusion, it must be remembered that the word "dipole" refers to a structural relationship and may be applied to many varieties of basic components. Dipoles may be considered as existing in terms of ions (as they are primarily referred to in this paper), or may even express the relationship between two surface charges on the spinning electron postulated by spectroscopic observation and theory.

Graphic representation, and until recently actual belief, has pictured electrons, atoms and molecules as spheres with much the same relative shapes, sizes and motions as the moons, planets and stars of astronomy. The development of wave mechanics has demanded that this theory undergo considerable alteration. An atom consists of a positive nucleus charge or charges placed in the center of one or more negative electron charges which are distributed with spherical symmetry through the surrounding space. The electron may be thought of in terms of the average field value of all the positions an electron point assumes in its complete enveloping motion around the nucleus; a negative charge symmetrically distributed in time and space. The density of this charge is an inverse ratio of the distance from the nucleus, extending to an indefinitely large distance. It becomes impossible to assign absolute values to atomic radii, and any measurements must be expressed in terms of the investigational approach and the circumstances under which the entity is considered to exist.

In general the possible arrangements of molecular structures are de-

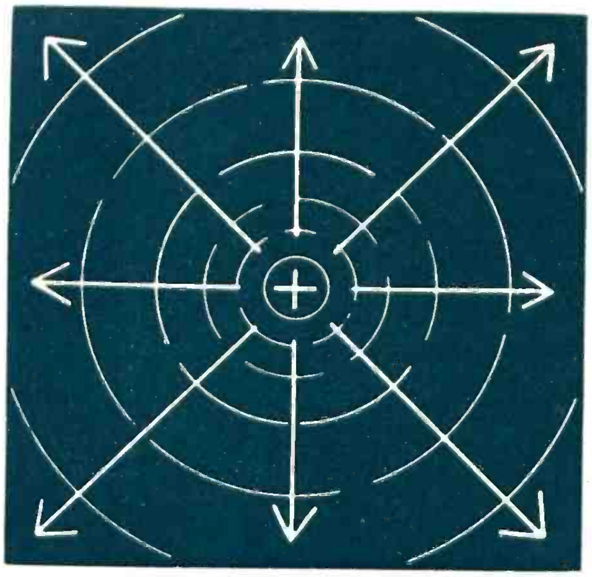
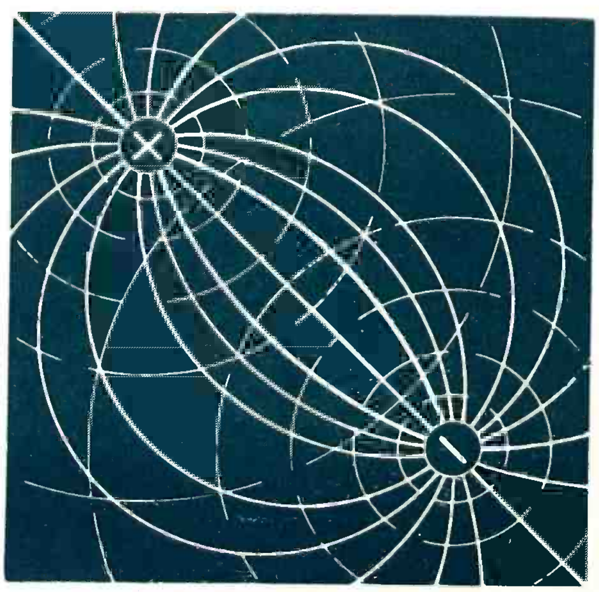


Fig. 2. Electrostatic field of a unipole.

pendent on the relative sizes of the atoms or ions from which they are built. It is evident that an atom of any specific diameter can be in surface contact with only a limited number of other atoms of definite diameter. The size which may be considered for the basic unit of an element will depend upon whether it exists as a neutral atom, a cation (cathode-ion lacking in one or more electrons with a resulting plus net charge), or an anion (anode-ion with an excess of one or more electrons and a resulting negative net charge); whether it exists alone, in intimate relationship to identities, or in co-structure with one or more different types of basic units. The forces which hold these various units of complex charge structures together, repulse them apart or maintain a final balance between them, are radionic. The entire intricate balance of electrons, protons, neutrons, mesotrons, (!), mass and/or energy is symmetrically balanced throughout the universe by

Fig. 3. Electrostatic field of a dipole.



radionic relationships in time and space.

A dielectric may contain permanent dipoles of constant moment, dipoles induced by an electric field, or both. The separation of electrical centers in an *induced* dipole takes place along the axis of the impressed field; hence, by definition, the polarization is strictly dependent on forces which are in no way affected by temperature. The polarization of *permanent* dipoles in a gaseous dielectric results from torque exerted by an impressed field. This torque is restrained only by thermal agitation which may be expressed as a temperature coefficient of polarizability for permanent dipoles. This latter condition appears to occur as well in a number of solids.

Considering isotropic dielectrics where r is the polarizability constant, M is the moment of a permanent dipole, n is the number of atoms per unit volume and $x = (1.38047 \pm 0.00026)10^{-16}$erg/1°C is Boltzman's constant, it is possible to show that the expression;

$$\frac{k-1}{k+2} = \frac{1}{9}\,\frac{nM^2}{xT},$$

at the absolute temperature T, satisfactorily states the relationships for permanent dipole conditions, and

$$\frac{k-1}{k+2} = \frac{1}{3}\,nr$$

will apply to effects caused by induced dipoles. Combining these for isotropic dielectrics containing both permanent and induced dipoles

$$\frac{k-1}{k+2} = \frac{1}{3}\,n\,(r + \frac{M^2}{3xT}).$$

Thus, a method is indicated for determining the relative extent to which the dielectric characteristics of a material depend on permanent and/or induced dipoles. Measurements of a number of gaseous dielectrics give empiric evidence of this mathematical demonstration that the ratio $\frac{k-1}{k+2}$ varies in proportion to the density if the temperature is held constant. By maintaining constant density and varying the temperature, data may be obtained and graphically represented as shown in Figure 6. If XY can be extrapolated to pass through O, the material contains permanent dipoles only. If XY parallels the abscissa, the dipoles are entirely induced.

The polarization of permanent dipoles has been considered so far in terms of electric currents of low frequency. It is evident that orientation with respect to an alternating field will require an oscillation of the dipoles at the same frequency. Various conditions (such as viscosity) would be expected to make complete rotation increasingly difficult with rising frequencies. Actual measurements of dielectric constants showing the inverse ratio to rising frequency above a certain point indicate the accuracy of this theory. At extremely high frequencies the effect of permanent dipoles may be completely lost and the dielectric constant of a material be traceable solely to the effect of induced dipoles. Again a method is apparent for separating the effects of induced and permanent dipoles and determining the relative quantity of each class in a specific dielectric.

Under resonant conditions the permanent dipole may be set into oscillation, so that the dielectric effect might increase sharply at certain frequencies and confuse the interpretation of experimental results.

The electrical center of a charge is analogous to the center of gravity. In electrically symmetrical molecules, such as carbon tetrachloride, the mean electrical center of the positive nucleii coincides with the center of all the electrons, and the molecule has no permanent dipolar characteristic. Where the construction is electrically unsymmetrical, as in water, every molecule is a permanent electric dipole. Examples of electrically symmetrical substances are nitrous oxide, oxygen and benzene. Molecules containing permanent dipoles are those of phenol, chloroform, hydrocyanic acid, ammonia, etc. The electric moment may be determined without difficulty for materials in a gaseous state, but calculations in connection with the molecules of liquids are considerably more complex. Specification of a permanent electric moment for a molecule postulates an unsymmetrical electric structure, and this knowledge may have value where crystallographic evidence is not available.

It is clear that the electrical symmetry of the molecular structure should be a consideration in selecting materials for use where the dielectric properties must remain stable over a wide range of temperatures and frequencies.

In considering crystalline structures, where the basic units are arranged in regular order, the internal equilibrium may be viewed with a minimum of variables. In supercooled liquids, such as glass, the obscure and seemingly random arrangements complicate the conception of equilibriums. Schematic representation shows the relationship in various simple patterns according to the imaginary progressive Figures 2, 3, 4, 5. It is important to note that sur-

(*Continued on page* 38)

Special Frequency Changers

By C. E. ATKINS
Tung-Sol Lamp Works, Inc.

A discussion of some less-commonly known conversion methods, that may find use in the expanding radionic art.

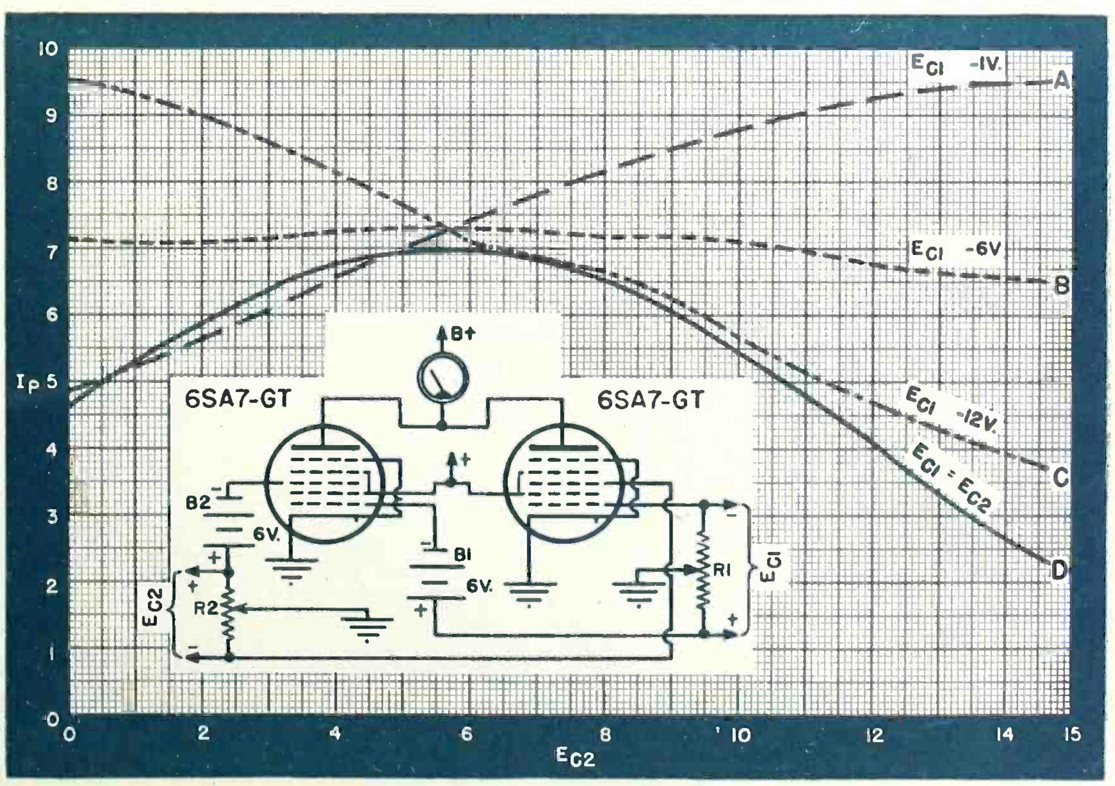
ONE of the most common operations in radionic engineering is frequency-changing. Straightforward amplification, simple frequency selection, or tuning and rectification are, of course, the processes with which the radionic engineer is most often concerned. There is, however, a host of applications where it is necessary to change one frequency to another, either higher or lower, fulfilling at the same time one or more specific requirements regarding the amplitude characteristic or the spectral distribution of the original frequency or frequencies. In the majority of instances, this is accomplished by simple heterodyning, using a diode or similar nonlinear impedance to which two or more frequencies are applied, or an electronic mixer such as the familiar pentagrid converter where the beating frequencies can be applied to separate control elements. Their mechanics are understood, as shown by profuse and profound literature written on the subject, and the extensive use to which these devices have been applied.

It is the purpose of this article to describe a few less-common frequency-changing arrangements. These are interesting mechanistically and have substantial practical value.

The circuit of Fig. 2, a streamlined version of a balanced modulator, works on the heterodyne principle but has, however, certain special features that set it apart from simple mixer circuits. Two multi-element tubes such as the 6SA7 have their cathodes, plates and screen grids parallel connected and their corresponding control grids push-pull connected to input transformers T_1 and T_2 arranged to employ input frequencies from two different sources. The parallel plates are connected through a suitable load impedance through the conventional "B" supply, and the screen grids are suitably polarized in the usual manner. The parallel cathodes are grounded through their adjustable impedance R_1 of a few hundred ohms. The drop across this resistor provides a bias voltage for the two tubes and serves an additional very important function, to be described later. Transformer T_1 feeds the outermost control grids in push-pull while the control grids closest to the cathodes are excited in push-pull by the output of transformer T_2. If either pair of grids is independently energized while the other pair of grids is quiescent, the tubes will supply equal and opposite currents to the load impedance R_2 and, accordingly, the net output voltage will be zero. If, however, both pairs of grids are simultaneously energized, sum and difference frequencies will appear across the output. This state of affairs is obtained because of the fact that in a modulating system sum and difference frequencies are produced by the cyclical blending of the input frequencies. This fact and the cancellation of the two input frequencies are illustrated in Fig. 1. The plates of two 6SA7's are connected in parallel and fed through a common plate current meter from a 250 volt "B" supply. The potentiometers R_1 and R_2 are so connected as to apply differential bias to the corresponding control grids of the 6SA7's. The potentiometer R_1 is fed with the indicated polarity from an adjustable d.c. source E_{c1}, while the potentiometer R_2 is supplied in like manner from a source E_{c2}. Batteries "B_1" and "B_2", each of 6 volts, were used to energize potentials on the positive legs of the potentiometers. This static measure corresponds approximately to the dynamic condition where these control grids are excited in push-pull with a.c.

The other electrodes are polarized in the conventional manner. With the arm of R_1 in center position and 6 volts applied across it, a bias of -3 volts is applied to each of the No. 1 control grids in the 6SA7. If now the arm of R_2 is likewise centered and the voltage across it varied from zero to 15 volts, differential increments are applied to the center pair of control grids in the 6SA7. The result of this

Fig. 1. Curves show in a graphical manner the operation of the circuit of Fig. 2.



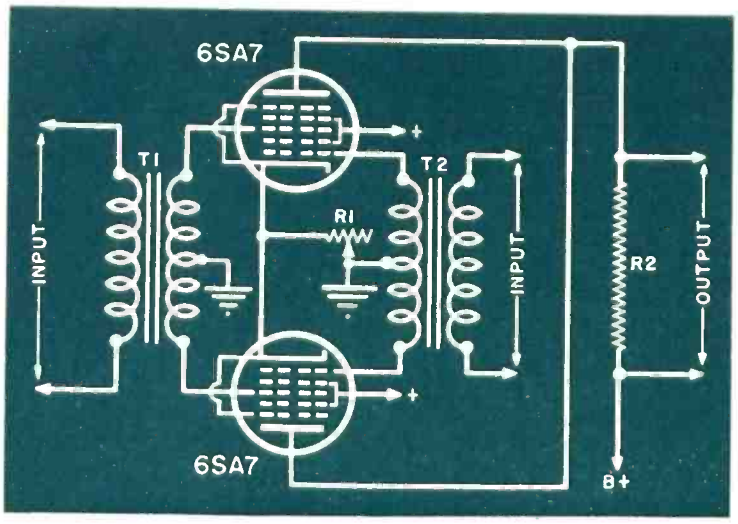


Fig. 2. Balanced modulator circuit, using cathode degeneration to reduce harmonic distortion.

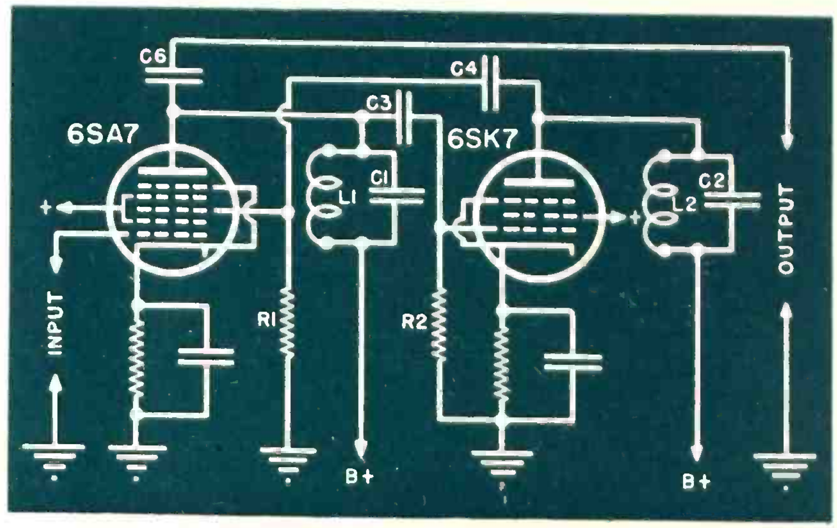


Fig. 3. A unique frequency-divider circuit, using two tubes, a 6SA7 and 6SK7, to obtain regeneration.

operation is shown in the curve B of Fig. 1. It can be seen that there is practically no change in plate current throughout this entire range. If now the voltage across R_1 is reduced, upsetting the voltage balance on the No. 1 control grids, the curve A is obtained. Under these conditions, there is a substantial variation of plate current with the differential voltage E_{c2}.

Likewise, curve C is typical of conditions when the voltage across R_1 is raised to a higher value (12 volts), thus putting −6 volts on one of the No. 1 grids and zero volts on the other. When the voltage across R_2 is then raised, the plate current drops, this latter condition being approximately the reciprocal of that illustrated by the curve A. Curve D, on the other hand, illustrates the case where both input voltages are raised and lowered together. Under these conditions the plate current first rises and then falls off again as the voltage becomes increasingly negative.

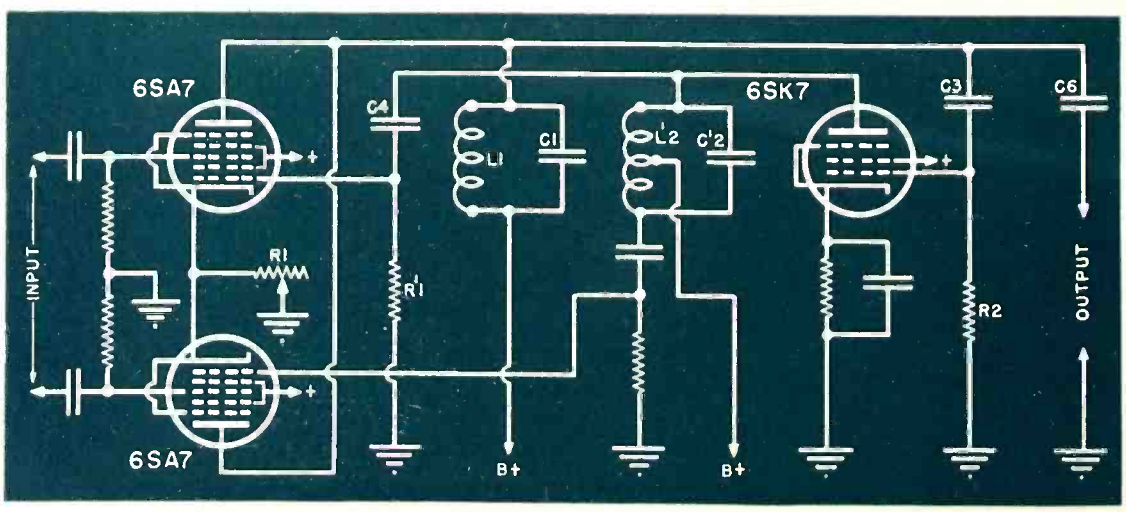
In the dynamic operating case, where two different frequencies are applied to the respective grids, there will be an interval during which the two wave-crests coincide; that is to say, they are exactly in phase. There will be another interval when the wave-crests are opposite and tend to cancel each other; that is to say, they are 180 degrees out-of-phase. The elapsed time between these two intervals is determined by the arithmetical difference between the two input frequencies. As the push-pull potentials execute their cyclical excursions from phase opposition through phase quadrature to phase harmony, the algebraic plate current follows a pattern corresponding to the production of sum and difference frequencies only and thus, in the output circuit there is but a perceptible trace of the original beating frequencies. Earlier balanced modulators, having push-pull output connections, eliminated but one of the beating frequencies by dynamic action, and selective circuits had to be depended upon for the erasure of the other input frequency. In many applications, the beating frequencies are so close together that this is a difficult thing to achieve, and in these cases the circuit of Fig. 2 is a fortunate solution.

Referring again to this figure, with particular reference to the adjustable resistor R_1, note that no by-pass condenser is shown. In experimental work with this system, the writer noticed that the signal applied to the inner grids of the modulator tubes produces a rather substantial even harmonic component which, if a large signal is applied, will result in troublesome harmonic distortion. The odd harmonics are canceled, because of the parallel output connection, but not so with the even harmonics. Fortunately, this distortion may be drastically reduced by the use of cathode degeneration which, while it eliminates the harmonic components in the output, has little or no effect on the heterodyne products.

This is true, because there is no cathode current component corresponding to the a.c. excitation on the No. 2 grids. This is due to the fact that the No. 2 control grid in a structure like the 6SA7 serves within wide limits to merely dictate the division of electrons between the inner and outer screen and plate. Negative increments on this grid do not change the cathode current, but cause more electrons to enter the first screen grid which results, of course, in a corresponding reduction in plate current. In like manner positive increments serve to raise the plate current at the expense of current to the inner screen. Since there is no cathode current corresponding to this voltage excursion, there can be no degeneration of this component. The resistor R_1 can be a few hundred ohms at audio and low radio frequency. At higher frequencies, of course, a different impedance element must be provided.

Frequency multipliers, like simple heterodyne converters, are fairly common. For the most part they depend upon distortion due to some non-linear vacuum tube characteristic for the production of harmonics which are then suitably sorted by the selective action of one or more tuned circuits. In heterodyne frequency-changers it is possible to retain relatively undistorted the amplitude characteristics or frequency side-bands of the original

Fig. 4. Frequency-divider employing a balanced modulator to reduce spurious responses.



after transposition. On the other hand, frequency mulpliers, dependent upon distortion as they are, cannot be used where strict amplitude reproduction is necessary.

Frequency dividers have been less generally employed, but are finding more and more applications as the art progresses. They are especially usefull in frequency measuring and stabilization systems, particularly in connection with FM transmitters.

The well-known multi-vibrator can be used for frequency division. This action depends upon the synchronization of the multi-vibrator which is actually oscillating in synchronism with a submultiple of the applied frequency. Of course, the multi-vibrator is often used for frequency multiplication as its output is rich in harmonics.

Fig. 3 shows an interesting frequency divider first proposed by Mr. J. W. Horton. (Patent No. 1,690,299.) In this circuit the input is applied to the No. 1 grid of a 6SA7, while the output is obtained through blocking condenser C_6 from the plate tank L_1C_1. This energy is also applied through blocking condenser C_3 to the control grid of a small r-f pentode such as the 6SK7. This tube has a tuned circuit L_2C_2 as a load and the voltage across this tank is applied through blocking condenser C_4 to the second control grid of the 6SA7. The 6SA7 can be referred to as a modulator, while the 6SK7 is a harmonic generator. In practice the tank L_1C_1 is tuned to the divided frequency, which is any reasonable sub-multiple of the input frequency f. When this input is first applied, there will appear across L_1C_1 random frequency components containing some element approximating that to which this circuit is tuned. This is due, in part, to the distortion produced in the 6SA7 and perhaps to shock excitation of the tank circuit by random variations in the tube's plate current.

Initially, and we are speaking of the brief interval following the application of the input signal f, this "harmonic" potential across the tank L_1C_1 will be minute.

Its application, however, to the grid of the harmonic generator will serve to produce a certain limited amount of harmonic voltage across the tank L_2C_2. If this tuned circuit resonates at a frequency differing from the original input signal f by an amount equal to the "divided" frequency across L_1C_1, it will naturally be harmonically related to this submultiple voltage. When this energy is applied through blocking condenser C_4 to the mixer grid of the 6SA7, it heterodynes with the incoming signal f producing sum and difference frequencies, one of which is the desired divided frequency. Numerical examples will perhaps clarify this operation.

Suppose we have a frequency of 1 megacycle which we desire to reduce to 250 kc. This calls for a division of 4 to 1. Tank L_1C_1 would then be tuned to 250 kc. and the voltage finally appearing across it would be utilized as the 250 kc. output. The third harmonic of 250 kc. is 750 kc., and we tune the tank circuit L_2C_2 to this frequency which is produced in the harmonic generator and applied to the 6SA7 for heterodyning with the original 1 megacycle input signal, yielding a resulting difference of 250 kc. as a sustained waveform across the tank L_1C_1. Of course, the fifth harmonic could have been used instead of the third with the same result. Harmonics of the original input signal f and various spurious responses will appear across the tank L_1C_1, and this may prove troublesome if the frequencies dealt with are low or close together.

Fig. 4 shows a modification of the circuit of Fig. 3 using the balanced modulator of Fig. 2 in order to reduce the number of spurious signals in the L_1C_1 tank circuit.

These frequency division techniques, like those employed for frequency multiplication, are unsuitable where it is necessary to change a frequency of a complex wave without altering its wave shape. Even a heterodyne system which exhibits exemplary fidelity in most of its applications cannot be used where a wave-form must be transposed completely intact. This may seem puzzling, because heterodyne conversion is used to faithfully render the intelligence of both frequency and amplitude modulation signals from one frequency value to another. The intelligence validity of the energy in these cases is simply a function of the frequency separation between a carrier and some relevant sidebands and their respective amplitude ratios. When such a multiplication of frequencies is heterodyned, this arithmetical relationship is unaltered. For instance, if a carrier of one megacycle is changed by heterodyning with a 1.456 megacycle signal to yield a .456 megacycle differential result, a thousand cycle sideband will be transferred unaltered, because it will necessarily represent the same sum and the same difference in either case. Where a frequency and its harmonics must be reduced, however, heterodyning would lead to an erroneous result. If, for instance, the one megacycle carrier had harmonics of definite amplitude occurring naturally at 2 megacycles, 3 megacycles, etc. and we wished to change it to a .1 megacycle signal having the same amplitudes of .2 megacycles, .3 megacycles, etc., we could not successfully employ the usual heterodyne means, unless we could somehow provide for paired beats between the harmonics of the respective signal and those of the beating oscillator.

(Continued on page 28)

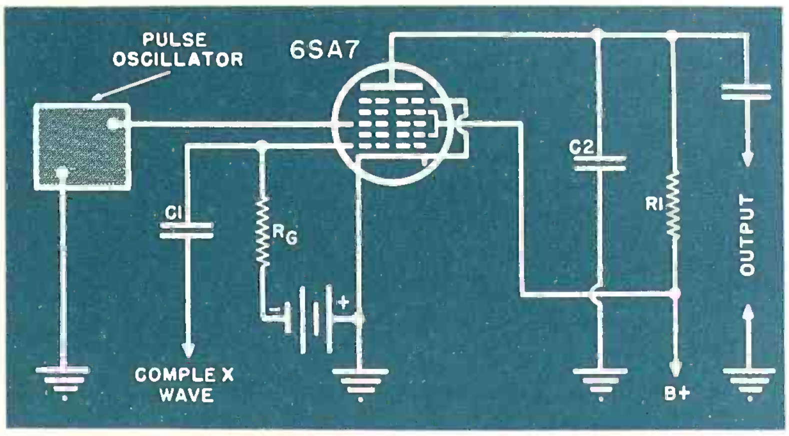
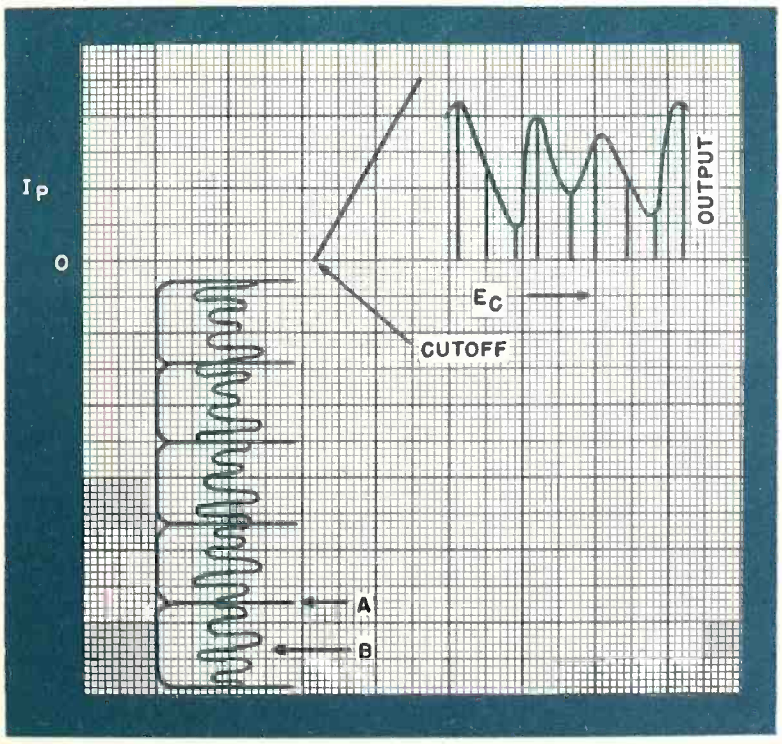


Fig. 5. Functional circuit of the Kent frequency-changer.

Fig. 6. Graph depicting the operation of circuit Fig. 5.



NOMOGRAM CONSTRUCTION

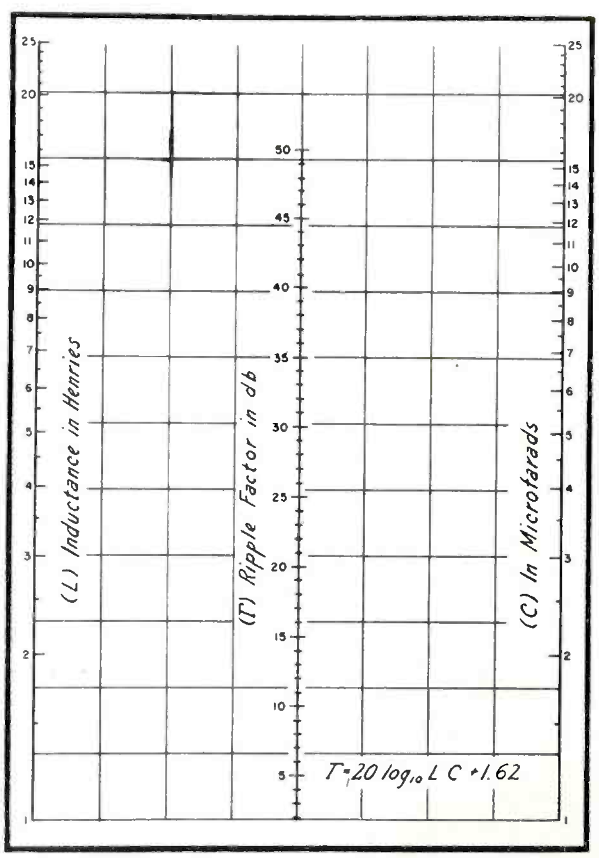
by S. KLAPMAN, Ph.D.
Physicist, Utah Radio Products Co.

The geometrical properties of three-way determinants, applied to the construction of various types of engineering nomographic charts.

A NOMOGRAM is a diagram representing a relationship between quantities, having scaled curves for each of the quantities appearing such that a straight line intersecting the curves will read values satisfying the relationship. The most common method for the construction of nomograms, heretofore, has been a combination of synthetic geometry, intuition, and luck. In this article a method will be shown by which nomograms based on three variables may be constructed in a straight forward manner. After presenting a general theory of nomogram construction, it becomes possible to state whether or not a given mathematical relationship can be represented by nomograms.

The general construction of a nomogram, as presented, is based upon the fundamental necessary and sufficient condition for three points (x_1, y_1), (x_2, y_2) and (x_3, y_3) to lie on a straight line as shown by the determinant:

Fig. 1. Ripple factor evaluation chart.



The group of nomograms included in this article are introduced for the sole purpose of illustrating the constructional methods for the various cases considered. Since these nomograms are too small for practical use by the radio technician and engineer, they shall reappear monthly as full page charts in RADIO NEWS *starting with this issue.*

$$\begin{vmatrix} x_1 & y_1 & 1 \\ x_2 & y_2 & 1 \\ x_3 & y_3 & 1 \end{vmatrix} = 0 \ldots\ldots\ldots\ldots (1)$$

Thus, if we have a functional relation between u, v and w, and this is put into form:

$$\begin{vmatrix} f_1(u) & g_1(u) & 1 \\ f_2(u) & g_2(u) & 1 \\ f_3(u) & g_3(u) & 1 \end{vmatrix} = 0 \ldots\ldots (2)$$

we shall have our desired result. Then a set of values for u, v, and w which satisfy the relation must also satisfy the determinant. Thus, if a curve for a function of u is drawn, with u a parameter such that $x = f_1(u)$ and $y = g_1(u)$ and the same is done for v and w, a straight edge laid across the three curves indicates the set u, v, and w thereby solving the relation.

From the theory so far presented, we see that we may put nomograms using three curves into 4 general classes.

Class I will comprise nomograms having only straight lines. The conditions for this are:

$$\left.\begin{aligned} f_1(u) &= k_1 g_1(u) + h_1 \\ f_2(v) &= k_2 g_2(v) + h_2 \\ f_3(w) &= k_3 g_3(v) + h_3 \end{aligned}\right\} \ldots\ldots\ldots\ldots (3)$$

where the k's and h's are constants which may equal zero. Class I is subdivided into three types, viz., three parallel lines, two parallel lines and no parallel lines.

Class II consists of nomograms having two straight lines and one curved line. Obviously, then, only two of the conditions (3) obtain. The subdivisions are two parallel lines and no parallel lines.

Class III consists of nomograms having one straight line, and Class IV contains nomograms having no straight lines.

Class I

Let us take as an example of 3 parallel lines:

$$f_1(u) + f_2(v) + f_3(w) = 0 \ldots\ldots\ldots\ldots (4)$$

This equation may be equally well described by:

$$\begin{vmatrix} -1 & f_1(u) & 1 \\ 0 & -\frac{1}{2} f_2(v) & 1 \\ 1 & f_3(w) & 1 \end{vmatrix} = 0 \ldots\ldots (5)$$

From the determinant, we deduce that we shall have three straight lines. Since the x-coordinate is constant for each, the lines are parallel. For actual construction, a modified determinant, which is still the original equation, is used. This determinant is obtained by the introduction of constants, the meaning of which will be clear after a glance at this constructional determinant:

$$\begin{vmatrix} -\delta_1 & \mu_1 f_1(u) & 1 \\ 0 & -\dfrac{\mu_1 \mu_3}{\mu_1 + \mu_3} f_2(v) & 1 \\ \delta_3 & \mu_3 f_3(w) & 1 \end{vmatrix} = 0 \ldots (6)$$

Where $\delta_1 \mu_3 = \delta_3 \mu_1$

From the determinant, we see that the v-line will be the y-axis. The u-line will be parallel to the y-axis but with $x = -\delta$, or to the left of the v-line. The scale factor for u will be given by μ_1. Thus, for a given value of u we find f_1, (u), multiply it by μ_1, and place a mark at y equal to this value and $x = -\delta$, and label it the value of u.

In constructing this nomogram, a choice is allowed of the distance between the u- and v-lines and the scale factors for the u- and w-lines. Having done this, the distance between the v- and w-lines and the scaling, of the v-lines are fixed. Therefore, in choosing these quantities, one must take into account the range over which one wishes the variables to lie in the space of the nomogram.

For a full-wave rectifier supplied with 60 cycles having an inductor input, where the resistance of the inductance is low in comparison to the load, the number of db the ripple voltage is below the average voltage is shown by[1]:

$$\Gamma - 1.62 = 20 \log_{10} L + 20 \log_{10} C \ldots (7)$$

Where C is in μfds. and Γ is in db. This equation is of the form: $f_1(u) + f_2(v) + f_3(w) = 0$ and therefore:

$$\begin{vmatrix} -\delta_1 & 20\,\mu_1 \log_{10} L & 1 \\ 0 & \frac{\mu_1 \mu_3}{\mu_1 + \mu_3}(\Gamma - 1.62) & 1 \\ \delta_3 & 20\mu_3 \log_{10} C & 1 \end{vmatrix} = 0 \ldots (8)$$

A useful range on inductance is 1 to 25 henries; for capacity, a range of 1 to 25 microfarads is useful. Since the numerical values of the ranges for both inductance and capacity are the same, their scale factors will be taken alike, $\mu_1 = \mu_3$. Thus $\delta_1 = \delta_3$, and therefore the Γ_{db} scale must be placed at four units in from either edge, or $\delta_1 = \delta_3 = 4$.

For L = 1 henry or C = 1 microfarad, $\log_{10} L$ or $\log_{10} C$ equals zero. To take full advantage of the paper therefore, the bottom of the sheet will be considered the x-axis. In order to obtain: μ_1 or μ_3.

$$11.84 = 20\,\mu \log_{10} 25 \ldots\ldots (9)$$

$$\mu = .42 \ldots\ldots (10)$$

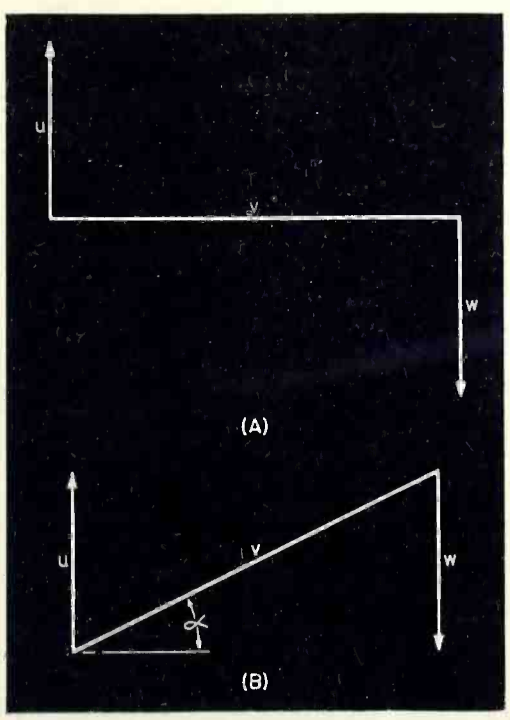
$$\text{Then} \quad \frac{\mu_1 \mu_3}{\mu_1 + \mu_3} = .21 \ldots\ldots (11)$$

Our determinant is then:

$$\begin{vmatrix} -4 & 8.47 \log_{10} L & 1 \\ 0 & .21\,(\Gamma - 1.62) & 1 \\ 4 & 8.47 \log_{10} C & 1 \end{vmatrix} = 0 \ldots (12)$$

This determinant gives all the information for the construction of the nomogram which appears in Fig. 1.

Fig. 2. General arrangement of lines for class 1 nomograms. (A) Illustrating lines drawn on a system of rectangular coordinates. (B) Illustrating lines drawn on a system of oblique coordinates.



Let us now consider the following determinant:

$$\begin{vmatrix} 0 & f_1(u) & 1 \\ \phi(v) & 0 & 1 \\ 1 & -f_3(w) & 1 \end{vmatrix} = 0 \ldots\ldots (13)$$

The u-curve will be coincident with the y-axis since x = o. The w-curve will be parallel to the y-axis, and the v-curve will be at right angles to both, in fact it will be the x-axis. The constructional determinant is:

$$\begin{vmatrix} 0 & \mu_1 f_1(u) & 1 \\ \frac{\mu_1 \delta_3 \phi(v)}{(\mu_1 - \mu_3)\phi(v) + \mu_3} & 0 & 1 \\ \delta_3 & -\mu_3 f_3(w) & 1 \end{vmatrix} = 0 \ldots (14)$$

Upon expanding either of the last two determinants, the equation represented is found to be

$$\frac{1}{\phi(v)} = 1 + \frac{f_3(w)}{f_1(u)} \ldots\ldots (15)$$

The one bad feature of making the nomogram according to this constructional determinant is that w is scaled downward. Thus, a great deal of space is necessary although it is not being used. If a system of oblique coordinates instead of rectangular coordinates could be used, we may be able to put the nomogram into the form shown in Fig. 2.

Since straight lines are represented by linear equations in an oblique coordinate system, it is still true that the type of determinant we have employed is the necessary and sufficient condition that three points lie on a straight line. If the x column is multiplied by sec α, where α is the angle the new x-axis makes with the old, then the x distances along the oblique x-axis are given. An example will show how such a nomogram is to be constructed.

The actual amplification A of a pentode stage, neglecting interelectrode capacitances, where the load impedance is small in comparison to the plate resistance is:

$$A = -G_m Z \ldots\ldots (16)$$

Where G_m is the transconductance, and Z is the load impedance. For the case of resistance-capacity coupling, and frequency high enough to neglect the capacitive reactances:

$$A = -G_m R_L \ldots\ldots (17)$$

Since one is interested usually in the absolute value of the gain, the negative sign will be dropped. In equation (15) if:

$$\Phi(v) = \frac{f_2(v)}{f_2(v) + 1},$$

then:

$$f_2(v) = \frac{f_1(u)}{f_3(w)},$$

and this is exactly our equation if: $A = f_1(u)$, $R_L = f_3(w)$, and $f_2(v) = G_m$. Thus the constructional determinant is:

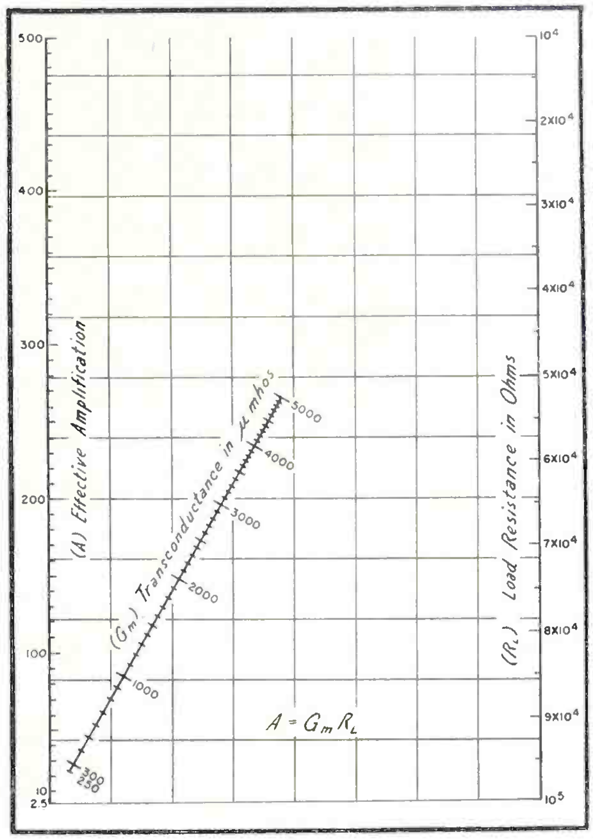


Fig. 3. Pentode amplification chart.

$$\begin{vmatrix} 0 & \mu_1 A & 1 \\ \frac{\mu_1 \delta_3 \frac{G_m}{G_m + 1}}{(\mu_1 - \mu_3)\frac{G_m}{G_m + 1} + \mu_3} & 0 & 1 \\ \delta_3 & -\mu_3 R_L & 1 \end{vmatrix} = 0 \ldots (18)$$

Let us take our ranges as follows:

$A = 2.5 - 500$

$R_L = 10K - .1M$ ohms.

A useful range for G_m is 250 to 5000 μmhos, as can be ascertained by a review of tube manuals.

The spread for A is $500 - 2.5 = 497.5$, therefore, we obtain μ_1 from $497.5\,\mu_1 = 12.53$, where we are still using our convention as to unit length of cross-section paper. (See Figure No. 3.) Thus $\mu_1 = .025$. Likewise, the spread for $R_L = 10^5 - 10^4 = 9 \cdot 10^4$ ohms. Accordingly, $9 \cdot 10^4 \mu_3 = 12.53$, or $\mu_3 = 1.39 \cdot 10^{-4}$.

Since we are going to use oblique axes, we may now determine the angle α. The intersection of the G_m-curve with the A-curve which we know is at the origin, is given by first finding where the low value of A lies with respect to A = O. This is $\mu_1 A = .025\,(2.5) = .0625$: Thus, the origin will lie .0625 below the divisions of the paper. We also know that for $G_m = \infty$, there is an intersection of the G_m-curve with the R_L-curve, and at this intersection $R_L = O$. Again, we find where our low value of R_L lies with respect to the point for $R_L = O$. This is $\mu_3 R_L = 1.39 \cdot 10^{-4} \cdot 10^4 = 1.39$. Therefore, the G_m-curve intersects the R_L-curve at a point 1.39 above the divisions of the paper. Thus tan $\alpha = 1.75$; $\alpha = 60°14'$.

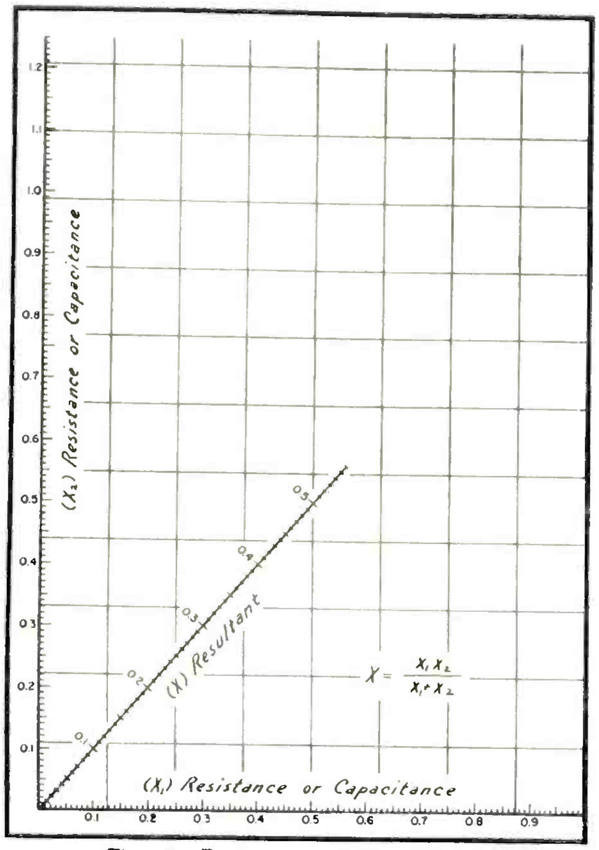


Fig. 4. Resistance or Capacitance Chart.

If now, y and x are rectangular cartesian coordinates by which we wish to express the G_m-curve

$$y = 1.75\,x - .063 \quad \text{.................. (19)}$$

represents the locus of the G_m-curve referred to rectangular coordinates.

The constructional determinant becomes after setting $\delta_3 = 8$,

$$\begin{vmatrix} 0 & .025\,A & 1 \\ \dfrac{.20G_m}{0.25G_m + 1.39\cdot10^{-4}} & 0 & 1 \\ 8 & -1.39\cdot10^{-4}\,R_L & 1 \end{vmatrix} = 0 \quad (20)$$

The x-coordinate of eq. (19) is given by $x = \dfrac{.20\,G_m}{.025G_m + 1.39\cdot10^{-4}}$.

From (20) and (19) the complete nomogram may be constructed.

An alternative method of constructing the G_m-curve is to fix two points by construction. The two points determine the locus of the G_m-curve and from (20) the curve may be calibrated. A point on the G_m-curve may be fixed by taking two sets of values of A and R_L for a fixed G and drawing straight lines from A to R_L. Where these lines intersect, is a point of the G_m-curve. For example, for $G_m = 500$ µmhos $= 5\times10^{-3}$ µmhos, take $R_L = 5 \times 10^4$ ohms, then $A = 250$, also for $R_L = 10^5$ ohms, $A = 500$. Now, coming back to the nomogram and drawing a straight line between $R_L = 5 \times 10^4$ and $A = 250$, and another straight line between $R_L = 10^5$ and $A = 500$, the intersection determines a point of the G_m-curve. Carrying out this procedure for another value of G_m determines another point. If a straight line is drawn between these points, we then have the locus of the G_m-curve.

What has been done above, assumed that we knew the locus was a straight line. This bit of information is furnished us by the constructional determinant. The constructional determinant also tells us the x-coordinate of the locus. That is, for a given G_m we may calculate the x-coordinate; that point of the G_m-curve which has the same x-coordinate as that calculated from G_m is calibrated with a value of the given G_m.

We now come to the last type under Class I, namely no parallel lines. A determinant for this purpose is

$$\begin{vmatrix} 0 & f_1(u) & 1 \\ f_2(v) & kf_2(v) + l & 1 \\ f_3(w) & 0 & 1 \end{vmatrix} = 0 \quad \text{....(21)}$$

which upon expanding gives:

$$f_2(v) = \frac{f_3(w)\,[f_1(u) - l]}{f_1(u) + k\,f_3(w)} \quad \text{..........(22)}$$

A constructional determinant for this equation can be found as:

$$\begin{vmatrix} 0 & \mu_1 f_1(u) & 1 \\ \delta_1 f_2(v) & \mu_1\{kf_2(v) + l\} & 1 \\ \delta_1 f_3(w) & 0 & 1 \end{vmatrix} = 0 \quad (24)$$

Thus far we have been dealing with nomograms which have had three arbitrary constructional parameters. Here we have a case of only two arbitrary parameters namely, μ_1 and δ_1, the scaling of the u-curve and the scaling of the w-curve respectively. We see that having picked these parameters, the scalings for the horizontal and vertical components of the v-curve are determined.

As an example of this type of nomogram, let us pick the equation giving the resultant capacity for two capacities in series or the resultant resistance for two resistors in parallel. Thus:

$$C = \frac{C_1\,C_2}{C_1 + C_2} \quad \text{............... (25)}$$

and

$$R = \frac{R_1\,R_2}{R_1 + R_2} \quad \text{............... (26)}$$

By double scaling each of the curves in the nomogram it will be feasible to have the same nomogram obviously serve both purposes. The reason for double scaling is only because the ranges of interest for C and R may not be the same.

If we set:

$$f_2(v) = C \text{ or } R, \qquad f_3(w) = C_1 \text{ or } R$$
$$f_1(u) = C_2 \text{ or } R_2, \qquad l = 0,\ k = 1 \quad (27)$$

then we have:

$$\begin{vmatrix} 0 & \mu_1 C_2 & 1 \\ \delta_1 C & \mu_1 C & 1 \\ \delta_1 C_1 & 0 & 1 \end{vmatrix} = 0 \quad \text{....(28)}$$

and

$$\begin{vmatrix} 0 & \mu_1 R_2 & 1 \\ \delta_1 R & \mu_1 R & 1 \\ \delta_1 R_1 & 0 & 1 \end{vmatrix} = 0 \quad \text{.. (29)}$$

Confining our attention to a nomogram involving the capacities, we understand readily that the roles of C_1 and C_2 can be interchanged. The scale factors δ_1 and μ_1 can be made equal or unequal depending upon the graphical and practical requirements of the particular problem. In this example the scale factors happen to be taken as $\delta_1 = 8$ and $\mu_1 = 9.38$. The range on C_1 is chosen as 0 to 1. The constructional determinant becomes:

$$\begin{vmatrix} 0 & 9.38\,C_2 & 1 \\ 8\,C & 9.38\,C & 1 \\ 8\,C_1 & 0 & 1 \end{vmatrix} = 0 \quad \text{.. (30)}$$

Equation (30) shows us that C_1 is scaled along the x-axis, C_2 is scaled along the y-axis, and C is scaled along a line whose angle with the positive x-axis is $\tan^{-1} \mu_1/\delta_1$. If the scalings on C_1 and C_2 had been taken the same, the angle between the C-curve and the positive axis would be 45°. More specifically this angle is given by $\tan^{-1} 9.38/8$. This example appears in Fig. 4.

We now come to the stage where two nomograms are combined so that a single setting may read more than 3 variables. Suppose we have two different relations, involving just 4 variables. Suppose two of these four variables are independent. If now in the constructional determinants the corresponding curves which represent the independent variables can be so arranged that they are exactly alike in the two nomograms, then a single setting will read simultaneously a solution involving all four equations.

As an example, let us consider the relationship between impedance, resistance, reactance, and phase angle as shown in Fig. 5.

$$Z^2 = R^2 + X^2 \quad \text{.................... (31)}$$

$$X = R\tan\theta \quad \text{...................... (32)}$$

$$(\delta_1\,\mu_3 = \delta_3\,\mu_1)$$

For equation (31)

$$\begin{vmatrix} -\delta_1 & \mu_1 R^2 & 1 \\ 0 & -\dfrac{\mu_1\,\mu_3}{\mu_1 + \mu_3} X^2 & 1 \\ \delta_3 & -\mu_3 Z^2 & 1 \end{vmatrix} = 0 \quad \text{..(33)}$$

For equation (32) written $\dfrac{X^2}{R^2} = \tan^2\theta$

$$\begin{vmatrix} 0 & \mu_1 X^2 & 1 \\ \dfrac{\mu_1\,\delta_3 \tan^2\theta}{\mu_1 \tan^2\theta + \mu_3} & 0 & 1 \\ \delta_3 & -\mu_3 R^2 & 1 \end{vmatrix} = 0 \quad \text{..(34)}$$

In equation (33) let us shift the origin along the x-axis, so that:

$$\begin{vmatrix} 0 & \mu_1 R^2 & 1 \\ \delta_1 & -\frac{\mu_1 \mu_3}{\mu_1 + \mu_3} X^2 & 1 \\ \delta_1 + \delta_3 & -\mu_3 Z^2 & 1 \end{vmatrix} = 0 \quad (35)$$

If now:

$$\delta_1 + \delta_3 = \delta_3'$$

$$\delta_1 + \delta_1 \frac{\mu_3}{\mu_1} = \frac{\delta_1}{\mu_1}(\mu_1 + \mu_3)$$

$$\delta_1 = \frac{\mu_1 \delta_3'}{\mu_1 + \mu_3}$$

Substituting in (35) and dropping the primes:

$$\begin{vmatrix} 0 & \mu_1 R^2 & 1 \\ \frac{\mu_1 \delta_3}{\mu_1 + \mu_3} & -\frac{\mu_1 \mu_3}{\mu_1 + \mu_3} X^2 & 1 \\ \delta_3 & -\mu_3 Z^2 & 1 \end{vmatrix} = 0 \quad (36)$$

In order to superpose the two nomograms, μ_1, $-\frac{\mu_1 \mu_3}{\mu_1 + \mu_3}$ of equation (36) should be equal respectively to $-\mu_3$ and μ_1 of equation (34). Another condition must obtain, namely that the x coordinates for the R-curves and X-curves should be the same for both equations (36) and (34). If first we determine the scale factors for equation (36), then we can manipulate equation (34) to obtain the desired conditions.

Let us set $\mu_1 = .15$, $\mu_3 = +.15$, and $\delta_3 = 8$, then (36) becomes:

$$\begin{vmatrix} 0 & .15R^2 & 1 \\ 4 & -.075\,X^2 & 1 \\ 8 & -.15\,Z^2 & 1 \end{vmatrix} = 0 \ldots\ldots\ldots (37)$$

We now manipulate (34) to obtain:

$$\begin{vmatrix} 0 & .15\,R^2 & 1 \\ \frac{8}{\tan^2\theta + 2} & 0 & 1 \\ 4 & -.074\,X^2 & 1 \end{vmatrix} = 0 \quad (38)$$

In (37) and (38) we shall use oblique axes. With respect to cartesian coordinates of the paper the x-axis of the nomogram is given by $y = 1.86x$. Thus the R-curve is scaled upwards at the y-axis of the paper. The Z-curve is scaled downward parallel to the y-axis at a distance $x = 8$. The X-curve is scaled downward from the x-axis of the nomogram at a distance of 4 units from the R-curve. Since the x-axis of the nomogram at the 0 point of the X-curve has paper coordinates given by $y = 1.86x$ or (4, 7.45), the X-curve is scaled down from this point. In scaling the θ-curve, we take for the X coordinate:

$$X = \frac{8}{\tan^2\theta + 2}$$

Having obtained **x**, we refer back to $y = 1.86x$ to obtain y.

CLASS II

Thus far all nomograms discussed have been examples containing straight lines. We shall now give an example of a nomogram in which one of the variables is scaled along a curve. The determinant with which we shall be dealing here is:

$$\begin{vmatrix} 0 & f(u) & 1 \\ g(v) & f(v) & 1 \\ 1 & f(w) & 1 \end{vmatrix} = 0 \quad (39)$$

This is equivalent to:

$$g(v)\,[f(u) - f(w)] = f(u) - f(v) \quad (40)$$

An equation which gives example of the above type of nomogram is the AC power output Pac of a tube[2]:

$$P_{AC} = \mu^2 E_g^2 \frac{R_L}{(r_p + R_L)^2} \ldots\ldots\ldots (41)$$

Where μ is the theoretical amplification of the tube, Eg is the grid voltage, r_p the plate resistance and R_L is the load resistance. If we define $A = \frac{\mu^2 Eg^2}{P_{AC}}$ then (41) can be written as:

$$\frac{R_L^{1/2}}{R_L^{1/2} - 1}[r_p - A^{1/2}] = r_p - \frac{R_L}{R_L^{1/2} - 1} \quad (42)$$

Equation (42) satisfies (39). It may be shown that the constructional determinant in this case is:

$$\begin{vmatrix} 0 & \mu_1 r_p & 1 \\ \frac{\mu_1 \delta_3 R_L^{1/2}}{\mu_1 R_L^{1/2} - \mu_3} & \frac{\mu_1 \mu_3 R_L}{\mu_1 R_L^{1/2} - \mu_3} & 1 \\ \delta_3 & \mu_3 A^{1/2} & 1 \end{vmatrix} = 0 \quad (43)$$

From (43), one may see a serious setback, namely, that the nomogram is undefined for $\mu_1 R_L^{1/2} = \mu_3$. In order to obviate this difficulty, μ_1 will be chosen positive and μ_3 negative. The ranges we shall choose are:

$r_p = 800\text{-}30000$ ohms

$R_L = 1000\text{-}200{,}000$ ohms

It is quite obvious that the determinant is based on knowing the ranges for r_p and $A^{1/2}$. By calculation, we find a range to choose for $A^{1/2}$ to be. Thus,

$A^{1/2} = 60\text{-}800$

$\mu_1 = 1.57 \cdot 10^{-4}$

$\mu_3 = -1.68 \cdot 10^{-2}$ and $\delta_3 = 8$

The zero of the r_p-curve then becomes a point 800 $(1.57 \cdot 10^{-4}) = .126$ below the cross-section; the zero of the $A^{1/2}$-curve becomes a point 60 $(1.68 \cdot 10^{-2}) = 1.008$ above the cross-section. Since again we are going to use oblique axes for the nomogram, the x-axis with respect to the cartesian coordinates of the paper is given by:

$$y = 1.70\,x - .13 \ldots\ldots\ldots (44)$$

Placing our attention on the R_L-curve in order to find its locus with respect to cartesian coordinates of the cross-section paper, we have:

$$x = \frac{8\,R_L^{1/2}}{R_L^{1/2} + 107.025} \ldots\ldots\ldots (45)$$

The oblique Y coordinate is:

$$Y = \frac{\mu_1 \mu_3 R_L}{\mu_1 R_L^{1/2} - \mu_3} = \frac{.23\,x^2}{x - 8} \ldots\ldots\ldots (46)$$

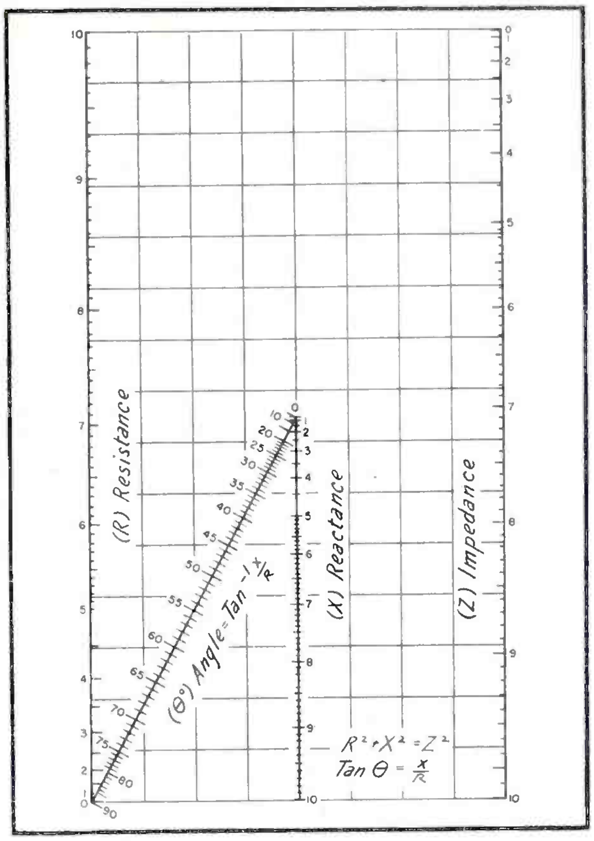


Fig. 5. Evaluation of complex numbers.

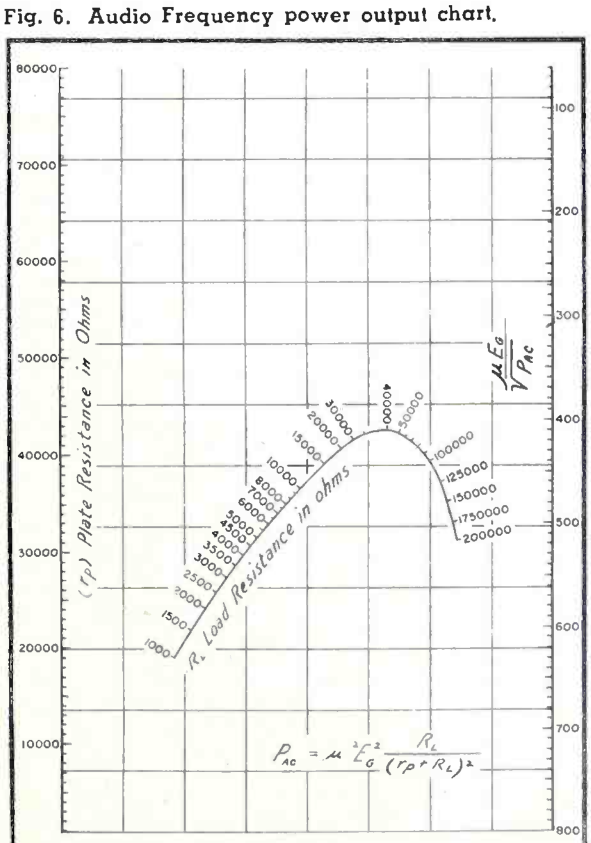
Then the y coordinate with respect to the cartesian coordinates is obtained by adding (44) to Y the oblique x-axis. Thus:

$$y = 1.70\,x - .13 + \frac{.23\,x^2}{x - 8} \ldots\ldots\ldots (47)$$

We shall not discuss further class II nor shall we class III and IV. For those interested in going further into nomography, the author recommends the book "The Nomogram" by Alcock and Jones.

(*Continued on page* 36)

Fig. 6. Audio Frequency power output chart.



CALIBRATION STANDARD FOR PHOTOTUBES

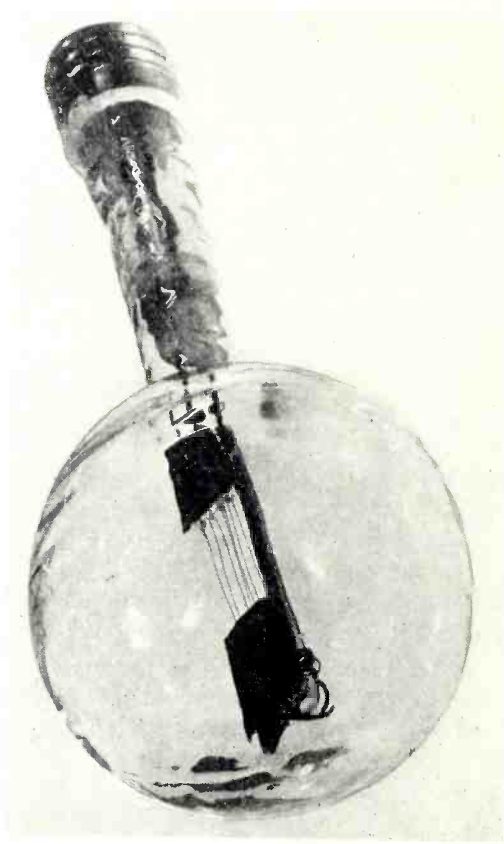
By S. R. WINTERS

The performance of a special optical standard for calibrating phototubes, within the infra-red and ultra-violet region of the spectrum.

THE world's first 20 solar observatories are being established along a 1,000-mile expanse of the Mississippi Valley. The word "sunfall" is knocking at the lexicographer's door for equal recognition with "rainfall" and "snowfall." The invisible ultraviolet rays are being harnessed in offices, laboratories, and public buildings as a potent germ-killing weapon. The amount of ozone is being measured. Excursions of airplanes into the stratosphere and daily expeditions of radiosonde apparatus into the upper atmosphere to "sound out" the weather—these and other factors place increasing emphasis on sky and solar radiation.

For about 10 years, the National Bureau of Standards has been exploring the ultraviolet, visible, and near-infra-red sections of the spectrum—employing radionic devices for boosting, by many thousand times, the photoelectric current too feeble for measurement by extremely sensitive thermopiles and galvanometers. Photoelectric cells or phototubes, not unlike individuals, vary, from tube to tube and from point to point on the electrode, in their responses to different ultraviolet wave-lengths. Heretofore, the inability to standardize them hindered the efforts of Government scientists to measure sky and solar radiation. Recently, however, two physicists—Ralph Stair of the Bureau of Standards and W. O. Smith of the Bureau of Plant Industry, U. S. Department of Agriculture—have designed and constructed an unusual type of tungsten-filament-in-quartz lamp which calibrates different phototubes. It is an important supplement to the standard instrument spectroradiometer in grading photoelectric cells with respect to their individual behaviour in measuring sun and sky radiation.

This tungsten-filament lamp (which may be constructed by radionic engineers, physicists, experimental laboratories, and physics departments of colleges), is encased in a fused-quartz envelope. As illustrated on page 17, this lamp is comprised of an 8-mil. straight filament, pure tungsten wire, enclosed in a globe-like, fused-quartz casing, 4 inches in diameter. The designers express preference for a straight, round wire instead of a coiled filament, since the former structural shape insures a more uniform temperature at every point on the wire. Black tungsten shields cover the ends of the filament and loops, as well as the molybdenum supporting hooks, thus preventing radiation from the cooler sections of the filament reaching the apparatus being calibrated.



A tungsten-filament-quartz standard lamp for accurately calibrating phototubes.

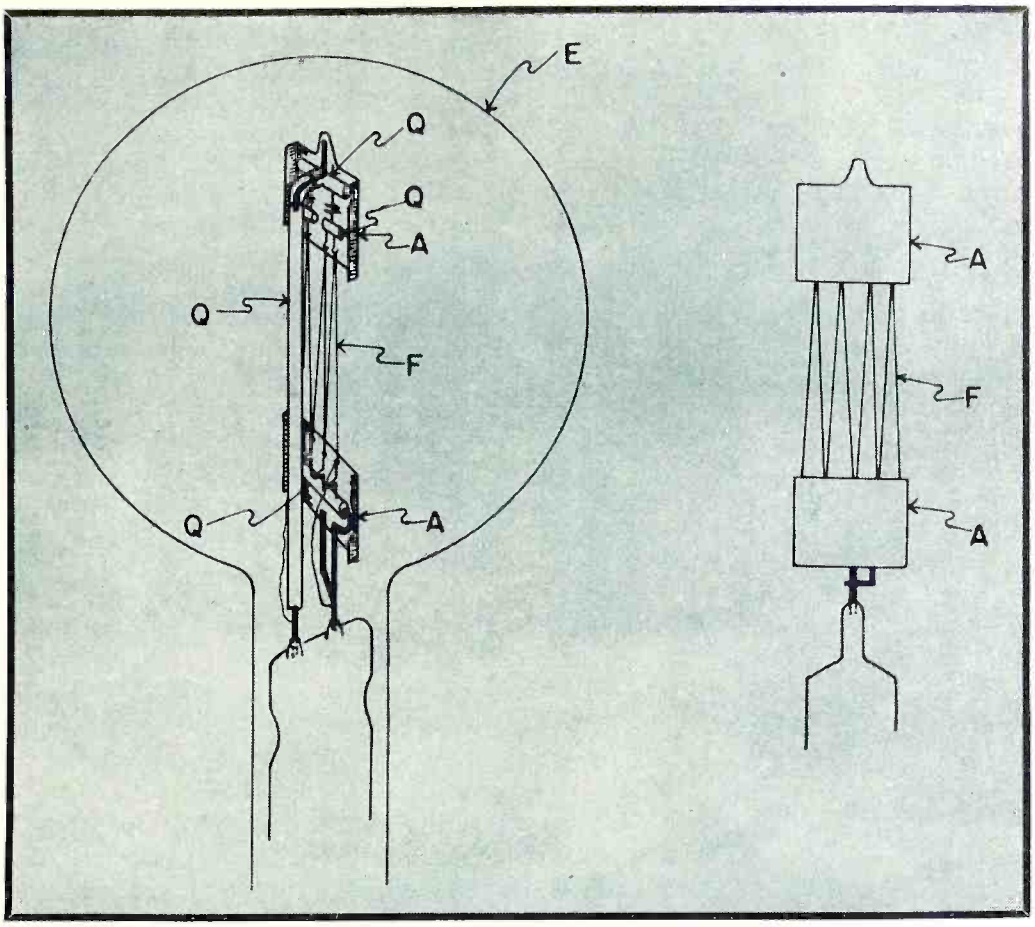
The filament has four evenly spaced "hairpin" loops, arranged in a plane, over an area of about ¾ by 1½ inches. The blackened tungsten shields were inserted in the lamp to simplify its use. The two physicists were aware that the shields would become heated and re-radiate energy at longer wavelengths, somewhat like feed-back radio circuits, becoming miniature broadcasting stations. However, not more than 10 per cent of the total energy radiated from the filament of the lamp can be absorbed by each shield, and inasmuch as the surface of each shield is greater by 10 times, than the surface of the filament, it is logical to assume that the entire energy radiated by each shield per unit area is less than one per-cent of that for the filament. Therefore, reasoned the designers of this device, the temperature attained by the shields is not excessively high and, consequently, the spectral distribution of the solar radiation is restricted to long wavelengths in the infra-red region, which fails to excite currently-designed phototubes.

This special lamp for photoelectric radiometric uses was filled with nitrogen, at a pressure of 0.6 of an atmosphere. Prior to sealing the filament in its fused-quartz envelope, it was "flashed" in nitrogen, at a temperature of 3,000 degrees K for one hour. Experiments have indicated that different batches of tungsten are not at variance in spectral emissivity, presumably because at high heat the impurities simply evaporate, leaving only pure wire. The designers of this lamp caution users against operating it at a temperature exceeding 2,800 degrees K, once it has been subjected to the necessary flashing action. Obviously, operation at excessive heat would shorten the lamp's life appreciably.

This novel type of lamp, according to preliminary tests, should be gauged to a power input of 500 watts—enough to insure a sufficient radiation output for the calibration of the phototubes by the filter method, particularly the photoelectric cells sensitive only to ultraviolet rays. The source of power, and its control, represent a special problem for consideration by radionic engineers designing this unique lamp. It is said to be convenient to have such a light unit operating slightly below 100 volts, simultaneously requiring less than 10 amperes, so that it may be controlled by available laboratory equipment. This end may be achieved by employing from 16 to 18 inches of 8-mil. tungsten wire as a filament. An abbreviated ribbon filament, functioning at a low voltage and high current, demands special equipment to control the power.

The envelope in which the lamp is encased is of high quality fused quartz, with the exception of its Pyrex press. This means that ultraviolet rays are transmitted with ease over the entire spectral region from 2,500 to 20,000 angstroms. This special structure, when coupled with the shields for forestalling radiation from the cooler ends and loops of the lamp filament reaching the phototube, obviates the necessity for an additional diaphragm, or lens, between the lamp and the photoelectric cell under critical examination. Thus, the phototube is completely and uniformly illuminated with rays of known spectral quality. Lack of homogeneity and variations in the thickness of the quartz envelope tend to produce a distorted image of the lamp filament. This is immaterial in the use of this lamp in "grading" the sensitivity of phototubes. If, however, it is necessary to employ an undistorted image of the filament for a specific purpose, the lamp can be equipped with a sealed-in window of polished fused quartz.

In applying this new lamp to the calibration of photoelectric tubes it is necessary to have precise information as to the distribution of the energy radiated from the lamp. This, for the particular device being described, is the function of the filament temperature, the emissivity of the material comprising the filament, and the transmission of the fused-quartz envelope. The spectral quality, however, of the radiation from a black body depends solely upon temperature. Stair and Smith, with due credit to Planck's radiation law, worked out the following mathematical formula for the operation of their unit.



Detail structure features of the standard quartz lamp; (A) shields, (F) filament, (E) quartz envelope, and (Q) quartz supports.

The intensity J_λ of the energy at wavelength λ is given by

$$J_\lambda = C_1 \lambda^{-5} \left(\epsilon^{C_2/\lambda T} - 1\right)^{-1} \ldots (1)$$

where C_1 is the first radition constant, C_2 is the second radiation constant, T is the absolute temperature, and ϵ

TABLE 1

Relative values of J_λ based on a value of J_λ of 10,000 (at $\lambda = 0.3500$ micron)

Wave Lengths (λ)	Blackbody temperatures								
	2,500° K	2,550° K	2,600° K	2,650° K	2,700° K	2,750° K	2,800° K	2,850° K	2,900° K
A									
2300	16	18	22	25	29	34	39	45	51
2350	24	28	32	38	43	49	56	64	72
2400	36	41	48	55	62	71	80	90	101
2450	52	60	69	78	88	99	112	125	138
2500	76	86	98	110	123	138	153	170	188
2550	108	122	136	152	169	188	207	228	250
2600	151	169	188	208	230	253	277	303	330
2650	208	231	255	280	307	336	366	397	430
2700	283	311	341	373	406	440	476	514	553
2750	380	415	451	490	529	571	614	659	705
2800	504	547	591	636	683	732	783	835	888
2850	662	712	764	818	873	930	988	1048	1109
2900	859	918	978	1040	1104	1169	1235	1303	1371
2950	1103	1171	1240	1311	1383	1456	1530	1605	1681
3000	1402	1480	1558	1637	1716	1798	1880	1962	2045
3050	1767	1853	1940	2027	2114	2202	2291	2379	2468
3100	2207	2301	2395	2488	2582	2676	2770	2863	2956
3150	2734	2834	2953	3032	3130	3227	3324	3421	3516
3200	3361	3464	3565	3666	3766	3865	3963	4059	4155
3250	4099	4202	4303	4403	4501	4597	4693	4786	4878
3300	4964	5062	5157	5250	5343	5434	5522	5609	5694
3350	5970	6057	6141	6224	6304	6382	6459	6534	6607
3400	7134	7201	7267	7332	7393	7454	7512	7569	7625
3450	8472	8511	8549	8586	8622	8657	8690	8723	8754
3500	10000	10000	10000	10000	10000	10000	10000	10000	10000

is the base of the natural logarithms. If λ is in microns, and T in degrees Kelvin, then C_1 has the value 3.732-$\times 10^4$ watt cm.^{2} and C_2 the value 14,360μ deg. (Wensel [1]); $J\lambda$ is then the radiant power, in watts, over a solid angle 2π, for unit area (cm.^{2}) of the black body per micron of wavelength. Values of $J\lambda$ can be calculated directly from equation 1. The value of the radiation constant C_2 was taken as 1.436 cm. deg. (14,360μ deg.), which has been shown in a recent summary by Wensel [1] to be the most probable value.

Values of the relative intensities, from equation 1, for wavelengths 2300 to 3500 A and for temperatures of 2,500° to 2,900° K are given in Table 1. This table was calculated for use in studies of the short wavelengths of ultraviolet solar radiation and should be very helpful, when ultraviolet radiation from the lamp is used. Values of $J\lambda$ relative to that for $\lambda = 0.3500$ micron are given for the temperature range 2,500° to 2,900° K in 50° increments. Wavelengths are given from 2300 to 3500 A in increments of 50 A.

The values given in Table 1 are $(J\lambda/J_{0.3500}) \bullet 10^4$; or what is equivalent, $J_{0.3500}$ has been set equal to 10,000. The constant C_1, it is to be observed, is not used in the calculations, since these are relative values. Values of ϵ^x used to compute the data of these tables were taken from tables [2] recently published by the Works Projects Administration.

The values tabulated in Table 1 are, in most cases, considered to be accurate to better than one in the final significant figure.

Data ([3], [4], [5], [6]) are to be found elsewhere that contain similar black body calculations for longer wavelengths. The tables of Skogland [4], for example, list values of $J\lambda/J_{0.5900}$ from 3200 to 7600 A for a temperature range of 2,000° K to 3,120° K. A slightly different value of the second radiation constant C_2 is used in most published work, but a correction factor has been determined [5]. Where it is desired to calculate a specific value, a short method of calculation given by Coblentz [3] is useful.

The emissivity of tungsten has been determined by several workers ([7], [8], [9], [10]) for different temperatures. The data, which appears to best represent the published values for the temperature range 2,700° to 2,900° K, is tabulated in Table 2. These values may be used in work of this kind throughout the range 2,500° to 2,900° K, since only relative values enter into the calculations.

As the transmission in the spectral region 2500 to 20,000 A of fused quartz, of the thickness (about 1 mm)

(Continued on page 33)

TABLE 2

An example of the application of the tungsten-in-quartz lamp in the determination of the spectral response of a photo-tube

(The spectral-response data (col. 5) is adjusted until the observed and calculated filter transmissions are in close agreement)

Wavelength	Relative radiation from black body at 2,737° K	Emissivity factor for tungsten	Relative radiation from tungsten at 2,737° K (Col. 2, col. 3)	Relative response of titanium phototube A	Filter Transmissions: Corex D	Filter Transmissions: Nillite	Filter Transmissions: Barium Flint—1	Filter Transmissions: Barium Flint—3	Relative radiation from tungsten times relative response of phototube (Col. 4, col. 5)	Relative radiation from tungsten times relative response of phototube times filter transmissions: Corex D	Nillite	Barium Flint—1	Barium Flint—3
1	2	3	4	5	6	7	8	9	10	11	12	13	14
A					%	%	%	%					
2560	195	0.393	76.6	.6	...	...	...	...	0.5	...	...	...	...
2580	221	.394	87.1	.8	...	...	...	...	.7	...	...	...	...
2600	247	.395	97.6	1.05	...	...	...	...	1.0	...	...	...	...
2620	277	.397	110.0	1.3	...	...	...	...	1.4	...	...	...	...
2640	311	.398	123.8	1.6	...	...	...	...	2.0	...	...	...	...
2660	350	.399	139.6	1.95	...	...	...	...	2.7	...	...	...	...
2680	390	.400	156	2.3	0.6	...	...	...	3.6	...	...	...	...
2700	432	.401	173	2.8	1.7	...	...	...	4.8	0.1	...	...	...
2720	480	.402	193	3.4	3.0	...	...	...	6.6	.2	...	...	...
2740	534	.403	215	4.1	4.3	...	...	...	8.8	.4	...	...	...
2760	593	.405	240	4.75	6.2	...	...	...	11.4	.7	...	...	...
2780	655	.406	266	5.35	8.2	...	...	...	14.2	1.2	...	...	...
2800	720	.407	293	6.0	11	...	...	...	17.6	1.9	...	...	...
2820	793	.408	324	6.6	14.5	...	...	...	21.4	3.1	...	...	...
2840	870	.410	357	7.1	18.5	...	...	...	25.3	4.7	...	...	...
2860	950	.411	390	7.6	23	0.3	...	...	29.6	6.8	0.1	...	...
2880	1030	.412	424	7.9	28	1.7	...	...	35.5	9.4	.6	...	...
2900	1153	.413	476	7.95	33	3.3	...	...	37.8	12.5	1.2	...	...
2920	1250	.415	519	7.9	38	5.3	...	...	41.0	15.6	2.2	...	...
2940	1370	.417	571	7.8	43	7.6	...	...	44.6	19.2	3.4	...	...
2960	1500	.419	629	7.45	47.5	10.0	...	...	46.9	22.3	4.7	...	...
2980	1630	.420	685	7.05	52	13.2	...	...	48.3	25.1	6.4	...	...
3000	1780	.422	751	6.6	56.3	16.5	...	...	49.6	27.9	8.2	...	...
3020	1930	.423	816	6.15	60.2	21	0.3	...	50.2	30.2	10.5	0.2	...
3040	2110	.424	895	5.8	63.5	26	1.4	...	51.9	33.0	13.5	.7	...
3060	2290	.426	976	5.25	66.6	31.5	3.0	...	51.2	34.1	16.1	1.5	...
3080	2480	.427	1059	4.85	69.5	36.5	5.5	...	51.4	35.7	18.8	2.8	...
3100	2650	.428	1134	4.4	72.3	41.8	9.3	...	49.9	36.1	20.9	4.6	...
3120	2890	.429	1240	4.0	74.8	46.5	14.5	0.1	49.6	37.1	23.1	7.2	0.05
3140	3110	.430	1338	3.65	76.8	51.5	21.5	.8	48.9	37.5	25.2	10.5	.39
3160	3350	.431	1444	3.2	78.7	56	28	2.5	46.2	36.4	25.9	12.9	1.16
3180	3600	.432	1555	2.85	80.0	60	34.5	5	44.3	35.4	26.6	15.3	2.22
3200	3840	.433	1663	2.45	81.3	64	41	8	40.8	33.2	26.1	16.7	3.26
3220	4120	.434	1789	2.1	82.4	67	47	12	37.6	31.0	25.2	17.7	4.51
3240	4420	.435	1923	1.7	83.4	70	53.5	18	32.7	27.3	22.9	17.5	5.89
3260	4730	.436	2062	1.35	84.4	73	59	25	27.8	23.5	20.3	16.4	6.96
3280	5060	.437	2212	1.00	85	75.8	64	32	22.1	18.8	16.8	14.1	7.07
3300	5410	.438	2370	.73	85.5	77.8	68	39	17.3	14.8	13.5	11.8	6.75
3320	5800	.439	2547	.46	86.3	79.5	71.5	45.5	11.7	10.1	9.3	8.4	5.33
3340	6200	.440	2728	.25	86.7	81	74.5	51	6.8	5.9	5.5	5.1	3.48
3360	6620	.441	2920	.13	87.3	82.5	77	56	3.8	3.3	3.1	2.9	2.13
3380	7030	.442	3008	.06	87.7	83.6	79	60	1.7	1.5	1.4	1.3	0.99
3400	7440	.443	3297	.03	88.3	84.5	80.5	64	0.9	0.8	0.8	0.7	.59
Total									1100.1	636.8	352.3	168.3	50.78
Calculated percentage transmission										57.9	32.0	15.3	4.61
Observed percentage transmission										59.0	31.9	14.8	5.83

Radionic Musical Instruments

By NICHOLAS LANGER

The application of radionic devices, in the form of audio-frequency oscillators, for the production of musical sounds.

THE close similarity between the properties of mechanical and electrical oscillations is so well known that it does not require any explanation. In fact, in the early development of our knowledge of electrical oscillations, their analogy with mechanical oscillations, the properties of which have been already fairly well known, has been widely recognized and utilized. This is clearly indicated by the circumstance that our present nomenclature employed in the science of electrical oscillations has been borrowed from acoustics. Also, this close analogy of concepts was extremely useful in the early development of radionics, as the relatively well developed art of acoustics would provide important clues for successfully solving problems related to electrical oscillatory phenomena.

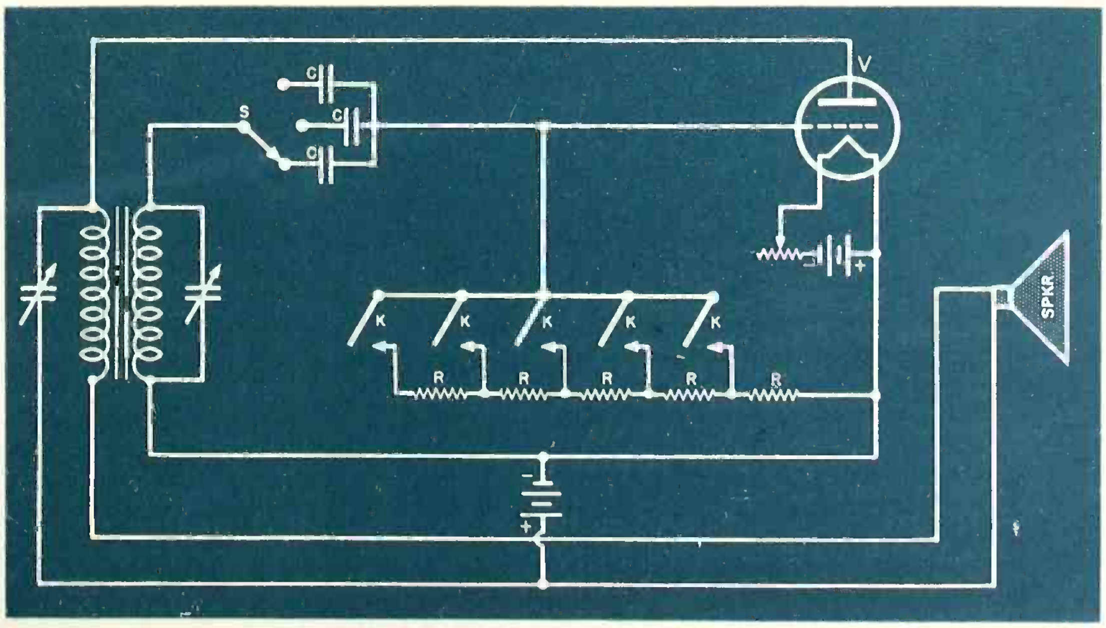
In the years gone by, the development of radionics in general and that of our knowledge of electrical oscillations in particular was so rapid that the time has now arrived to reverse this historical process. It seems that by applying the concepts developed in the study of radionics, the science of acoustics could be advanced to a considerable extent.

The development of broadcasting and of modern sound recording has greatly increased our knowledge of sound, particularly that of musical sounds. The transmission, recording, and reproduction of music has presented some of the earliest and most complex problems with which radionics had to deal. In broadcasting and also in modern sound recording, the first step generally consists in converting mechanical oscillations into electrical oscillations. After a complex combination of steps, these electrical oscillations are again returned into the form of mechanical oscillations at the receiving or reproducing end.

From this well-known cycle, during which the sound is represented at least once in the form of electrical oscillations, it is obvious that musical sounds can be directly produced by means of electrical oscillators, the output of which is converted into sound by means of loudspeakers and similar reproducers. As a matter of fact, the practical development of radionics, particularly that of radio receivers, eliminated the necessity of abstract thinking processes for arriving to this conclusion. The early radio receiver was such a prodigious source of self-produced sounds, musical and otherwise, that great effort had to be made to keep these parasitic noises under control. But, even long before the advent of broadcasting, it was recognized that electrical oscillations of audio frequency may be employed as sources for the production of musical sounds, and there was hardly any method of producing electrical oscillations which at some time or another did not form the basis of an attempt toward the construction of a radionic musical instrument.

In a broad sense, the problem of designing a radionic musical instrument may be separated into three parts. The first one of these consists in the generation of electrical oscillations having frequencies covering the full musical range, that is from about 25 to about 4500 cycles-per-second. According to whether we are satisfied with monophonic music, that is a single musical note at a time, or wish to produce polyphonic music, that is a plurality of up to 8 or 10 musical notes simultaneously, this may require from one to 88, and more, oscillation generators. The second part of the problem comprises the provision of waveforms or, musically speaking, tone colors which are satisfactory and pleasing. In general, pure sinusoidal oscillations, when converted into sound, are not satisfactory from the musical point of view as they impress us as empty and meaningless. Practically all of the traditional musical instruments produce oscillations having a more or less complex harmonic structure in which harmonics up to the 15th, and even higher, are present with small but effective amplitudes. This complex harmonic structure has to be provided either by synthetically building it up from a plurality of substantially sinusoidal oscillations, or analytically, by directly producing a substantially unbroken series of harmonics and subsequently removing certain of such harmonics by means of suitable networks. Finally, as the last part of the problem, in a practical radionic musical instrument, provision has to be made for controlling the production of oscillations or at least their transfer to the sound producer between zero and maximum amplitude

Fig. 1. A low-frequency regenerative oscillator, patented by de Forest in 1915.



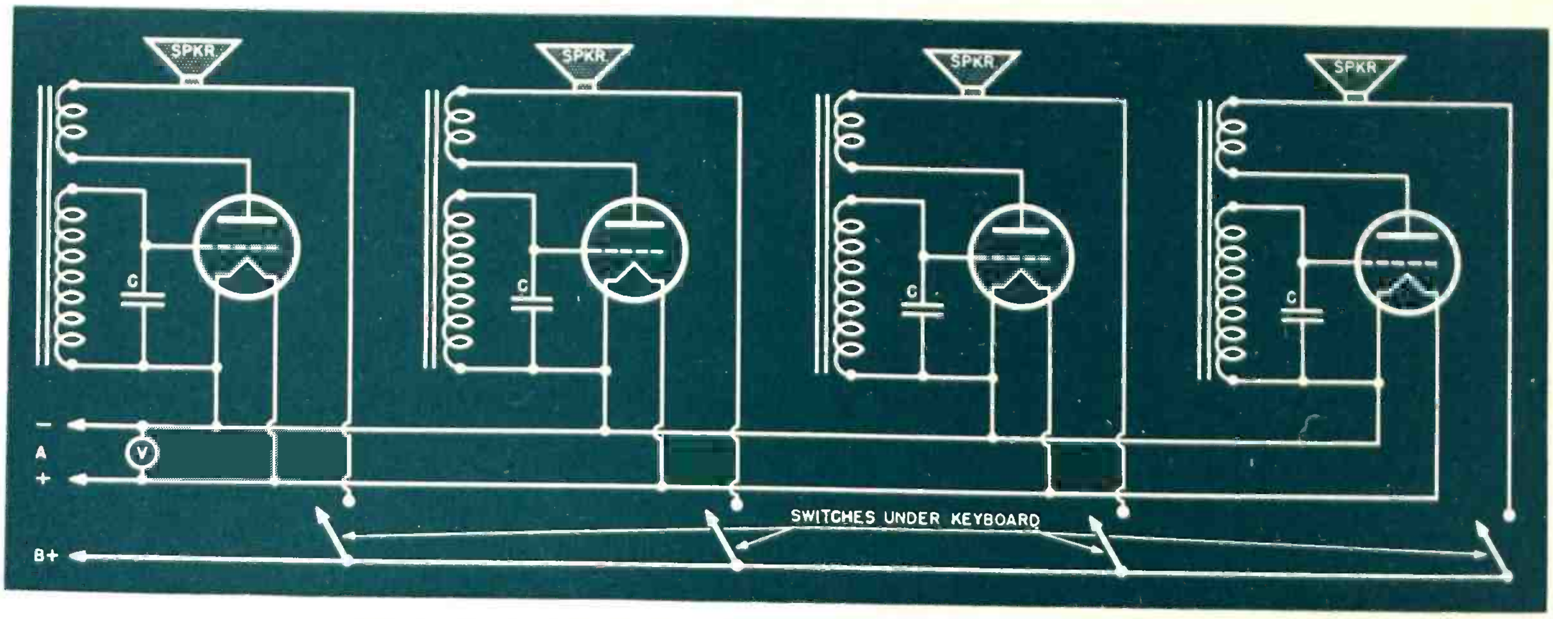


Fig. 2. Circuit of the Pianorad showing 4 of the 25 oscillator tubes used.

with all possible shadings between. Also, various auxiliary effects are desirable, if not absolutely necessary, for equaling or even surpassing the technical possibilities of the traditional musical instruments. These auxiliary effects may involve varying the harmonic structure or tone color within wide limits, controlling the envelope or attack and decay characteristics of the oscillations, or providing slight frequency or amplitude modulation of the oscillatory output, known as vibrato or tremulant in music. From the foregoing considerations, it is clear that while the fundamental requirements of radionic music production are extremely simple, the problem becomes very complex when it is desired to duplicate the performance of the traditional musical instruments, representing the result of growth and development over the period of many centuries.

It is convenient to classify the radionic musical instruments according to the type of generator employed for producing the electrical oscillations of musical frequency. All of the known systems may be divided into two large groups. One of these groups employs purely radionic means such as tubes or other discharge devices for the generation of electrical oscillations. The instruments of the other group employ a combination of mechanical and radionic means for the generation of electrical oscillations.

The present article discusses the radionic musical instruments in the first group while the instruments employing the principle of combining mechanical and radionic means and the general engineering aspects of these instruments will be dealt with in two separate articles.

The first radionic musical instrument to acquire commercial importance was a direct outgrowth of the beat-frequency oscillations of variable frequency experienced in early regenerative receivers as the result of hand capacity. This instrument was the Aetherophone, or Theremin, invented by Leon Theremin and introduced to the public in 1927.

The Theremin is essentially a beat-frequency oscillator comprising a high frequency oscillator of fixed frequency and another high frequency oscillator, the frequency of which may be varied by the effect of hand capacity on antenna or pitch control rod. These two high frequency oscillations are amplified by means of vacuum tubes and the resultant oscillations are introduced into the detector tube. The detected oscillations of audio frequency are further amplified by means of low frequency amplifier tubes and are finally made audible in a loud speaker. The pitch of the note produced is adjusted in obvious manner by changing the position of the operator's right hand with respect to the pitch control rod.

Theremin has also developed an ingenious method for controlling the volume by means of the hand capacity effect. This is accomplished by means of a third high-frequency oscillator, the output of which supplies the heater current for one of the amplifier tubes. This high frequency circuit is inductively coupled with an absorption circuit provided with a volume control rod. The circuit constants are so determined that in the absence of any hand capacity effect on the rod, the transfer of high frequency energy to the filament of the amplifier tube will be the highest so that this tube will operate with its maximum amplification. By approaching the left hand of the operator to the volume control rod, the tuning of the absorption circuit will be changed and the amplification may be reduced to any desired level.

While the construction of the instrument, particularly the method of determining the pitch and the volume, was quite ingenious, its playing technique was indeterminate and extremely difficult. It was practically impossible to change the output note from one frequency to another without going through all the intermediate frequencies. In the hands of a highly trained operator, particularly in the execution of slow movements, it was occasionally capable of very attractive musical effects, but its tone color and delivery tended to become monotonous and tiresome. These inherent disadvantages prevented commercial success of the Theremin although it was manufactured and marketed by the Radio Corporation of America for a short time.

Mager and later Martenot have built instruments of the beat-frequency oscillator type which are hardly different from that of Theremin except for the method by means of which the frequency of the variable high frequency oscillator is adjusted. Mager merely provided a variable condenser for the adjustment of the frequency.

The Martenot, named after its inventor, likewise changes the capacity in one of the high-frequency oscillator circuits but provides a variable capacity in the form of a fixed metal rail and a displaceable flexible metal cable parallel to and close to said rail. One end of this cable is wound up on half of a double drum, the other end is attached to an insulated cord, the end of which is wound upon the other half of the drum. A ring or a similar finger piece may be moved by the operator along a scale which, in the practical Martenot, has taken the form of a dummy keyboard thus permitting direct association of the frequency with this most familiar form of an operating mechanism. An interesting feature of the Martenot is the provision of a series of tuning screws for the accurate adjustment of the capacity at predetermined points of rail thereby to obtain exact correspondence of the frequencies produced by the beat-frequency oscillator with the notes indicated by the corresponding keys of the dummy keyboard.

While the instruments of Mager and of Martenot were superior to the Theremin with respect to the facility of operation, they suffered from the disadvantage of frequency drift, which is common to all instruments based on beat-frequency oscillators. Therefore, at present, these instruments are only of historical interest.

The difficulty of frequency instability is considerably reduced by employing vacuum tube oscillators directly producing audio frequencies. It is worth noting that the first suggestion in this direction was made by Lee de Forest who, in one of his early patents filed in 1915, disclosed an electrical musical instrument employing an oscillator of this type. As it will be seen in Fig. 1, the de Forest instrument comprises a tube V connected in a low frequency regenerative oscillator circuit. Provision is made for changing the frequency by changing the grid resistance R in steps adjustable by keys K or by changing the grid capacity C by means of switch S. Thus, this early instrument already shows practically all of the essential elements of modern radionic musical instruments of the monophonic or melody type.

The Hellertion invented by Helberger and Lertes is closely similar to the de Forest instrument. It comprises a conventional audio-frequency oscillator of the feedback type, including a triode, a tuned circuit and a feedback coil in series with a speaker. The frequency is adjusted by changing the grid bias voltage by means of a flexible metallic playing band or ribbon, making contact with portions of an elongated potentiometer element. A suitable taper may be incorporated into the potentiometer in order to obtain linear distribution of the frequency with respect to the length. The general pitch of the instrument is adjusted by controlling the filament current through a resistance.

Some practical forms of the Hellertion have made provision for polyphonic play by arranging up to four oscillators of the described type with their respective playing "manuals" or ribbons in closely parallel-spaced position so that they could be manipulated by fingers of the same hand.

The Spherophon of Mager also closely follows the de Forest instrument with the only difference that the capacity of the tuned circuit is changed for adjusting the frequency. In this instrument Mager likewise provides the conventional feed-back oscillator comprising a tube in combination with tuning coil and a feedback coil. A chain of small condensers is normally connected across the tuning coil by means of initially closed key-operated switches. By actuating any one of the switches, a corresponding portion of the capacity chain may be disconnected thereby increasing the frequency by a predetermined amount. The oscillations are amplified by a second tube, and are made audible in a loud speaker.

The regenerative vacuum tube oscillator principle is likewise employed by Givelet whose instrument comprises a low-frequency oscillator of the Hartley type. Givelet's instrument comprises a triode having a condenser permanently connected between the plate and the grid. A plurality of tapped inductances is provided and may be selectively connected into oscillation-producing relation with tube and condenser by means of key-operated switches. The output of the oscillator is rendered audible by means of a group of speakers, which may be individually connected into the plate circuit by means of a rotary switch. Each of the speakers is of a different type or construction so that somewhat different tone colors may be obtained by connecting speakers of different audio frequency response into the output circuit. Tuning is made possible by means of movable iron cores, individually provided for each inductance. It will be noted that this instrument, same as Mager's Spherophon, is designed with fixed frequency intervals corresponding to successive notes of the tempered scale, a separate switching key being coordinated to each note. Therefore, the frequency stability of the oscillator is very essential in maintaining the proper pitch intervals for the respective notes. In the present case, this is accomplished by careful design of the oscillator and by the selection of a favorable LC ratio.

While the instrument just described is monophonic, Givelet in cooperation with Coupleaux, has also built a number of polyphonic instruments, or organs, in which a separate oscillator of the described character is provided for each note. Some of these organs are quite elaborate, thus the organ installed at the church of Villemomble, near Paris, has two manual keyboards of 56 keys each, and a pedal keyboard of 32 keys. Although the cost of such organs must have been quite high in view of the large number of high-quality oscillators incorporated, in general not a great deal lower than that of a pipe organ of

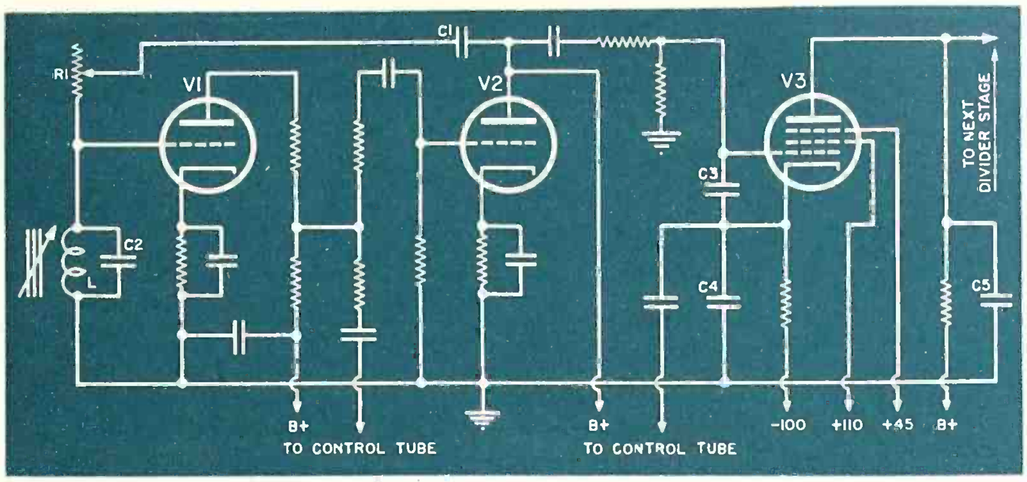
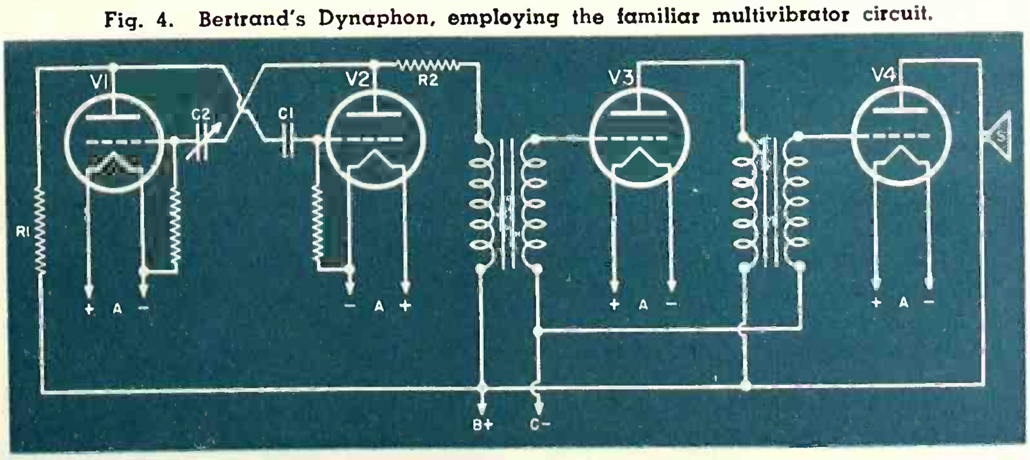


Fig. 3. Fundamental circuit of the Novachord, showing one of the "master" oscillators.

Fig. 4. Bertrand's Dynaphon, employing the familiar multivibrator circuit.



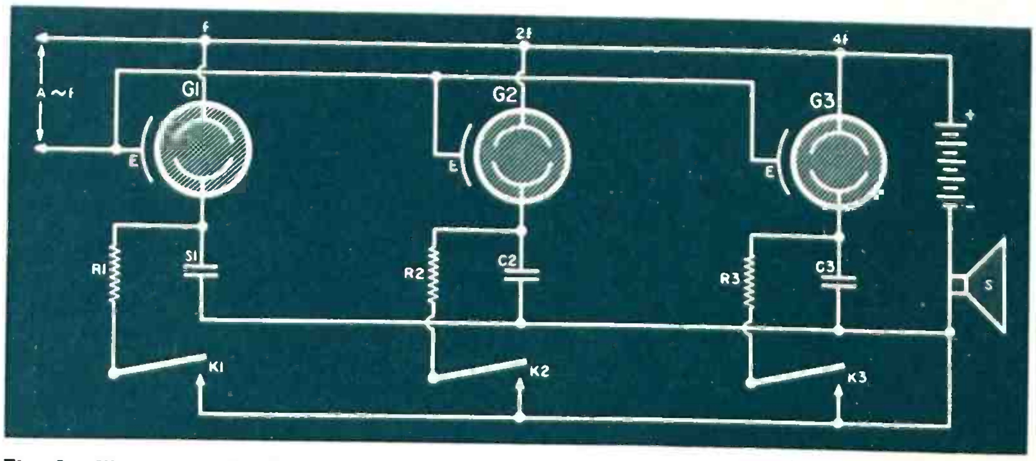


Fig. 5. Illustrating the fundamental principle of one of the author's polyphonic instruments.

moderate scope, substantial advantages are claimed in the way of reduced space requirements and in the greatly lowered cost of installation and upkeep. The relatively high cost of this type of radionic organ nevertheless has restricted their application to church and auditorium installations and has prevented their large scale use as small residential organs.

It is interesting to note that an attempt toward producing a polyphonic radionic organ by means of a large number of audio-frequency oscillators has been made in this country as early as in 1926 by H. Gernsback. His organ, or as called by the inventor, the Pianorad, comprised 25 oscillator tubes in the conventional ticker coil feed-back circuit. As, presumably in the absence of adequate shielding and decoupling, considerable trouble was experienced by cross-modulation in a common sound reproducer, a separate speaker has been provided for each oscillator. Although this instrument was actually built and was even broadcasted several times, it was not followed up by any effort to commercialize it. The circuit of the Pianorad is shown in Fig. 2, which should be self-explanatory.

One of the most interesting instruments of this class and probably the first polyphonic instrument with purely radionic oscillation generators which was ever manufactured on a commercial scale is the Novachord of Laurens Hammond, placed on the market in 1939.

In the Novachord, the electrical oscillations for the twelve notes of the highest octave are provided by resonant vacuum tube oscillators, while the oscillations for the remaining notes are provided by successive stages of a cascaded frequency divider system. Each tube of this system receives a signal from the preceding tube in the cascaded series. The output of each tube contains a fundamental frequency together with various harmonics of this fundamental. The frequency-divider tubes themselves do not function as oscillators, and in the absence of an input signal, the output signal disappears. This distinguishes the Novachord circuit from prior frequency divider circuits in which tubes independently oscillating at harmonically related frequencies are "locked" or synchronized.

The fundamental circuit of the Novachord is illustrated in Fig. 3, showing one of the "master" oscillators together with one frequency divider stage. The "master" oscillator for a single note comprises a pair of triodes V-1 and V-2 which in actual practice are united in a single envelope. The plate of tube V-2 is connected through a condenser C-1 and a variable resistance R-1 with the grid of tube V-1 to provide feed back in the proper phase relation. The frequency of the oscillations produced is controlled by a resonant circuit L, C-2 connected into the grid circuit of tube V-1. The frequency stability of this oscillator is assured by the special high-Q construction of coil L, the exact frequency being adjusted by means of a displaceable iron core. In general, the output of the first triode is substantially sinusoidal, while that of the second triode is quite rich in harmonics due to operating this tube nearly at the cut-off potential.

Part of the output of the second triode V-2 is introduced into the frequency divider tube V-3 which is a pentode with sharp cut-off characteristics. Except for the values of the circuit constants, this tube and the following divider tubes are interconnected in a manner similar to a conventional resistance-coupled amplifier with self-biased tubes, there being, however, two additional condensers, C-3 and C-5, provided in each stage. By proper selection of the circuit constants, the cathode is caused to float at such direct current potential with respect to ground that the voltage effective between cathode and grid will be close to the cutoff voltage of the tube whereby non-linear operation will follow.

As a result of this non-linear operation, small changes of the grid voltage in the positive direction with respect to the cathode voltage will cause a substantial surge of plate current, while similar changes of the grid voltage in the negative direction will have substantially no effect on the already small plate current. Due to the time constant effect of condensers C-3 and C-4, determining the interdependence of grid and cathode potentials, only every other positive excursion of the grid will result in producing plate current pulses. Of course, the outlined procedure of frequency division or halving is repeated as many times as is necessary, there being 6 or 7 such stages provided in a complete instrument.

The output of electrical oscillations is not directly introduced into the amplifier system, but through control tubes of which one is provided for each note. While this arrangement adds substantially to the cost of the instrument, it provides great advantages by performing a number of functions of widely different character. Thus, the arrangement of a control tube between each oscillation source and the common output load assures complete decoupling. Furthermore, the control tube is also utilized to determine the attack and decay characteristics of the output notes, to eliminate key clicks and other undesirable transients, and finally to vary the harmonic structure of the produced oscillations within wide limits. Therefore, the system of control tubes plays an important part in determining the overall performance of the Novachord as a musical instrument.

In general, same as the other instruments of Hammond, the Novachord is characterized by excellent engineering. If the instrument was not quite as successful commercially as the Hammond Organ, this was probably due to the fact that it cannot be definitely classified with any group of the traditional musical instruments. Its range of frequency and of tone colors are comparable to those of the organ which it even surpasses with respect to the possibility of producing percussion type effects of great diversity. On the other hand, it lacks the multiple keyboard arrangement, manual and pedal, of the organ, so that it is incapable of simultaneously carrying a plurality of tones, each having a distinct tone color and rhythmic pattern of its own. Presumably considerations of cost rather than of technical difficulties forced Hammond to thus restrict the scope of an otherwise meritorious instrument, and it is quite possible that ultimately the Novachord will be expanded to a scope comparable to that of an organ.

In contrast to the Novachord, a tube-operated solo instrument of the Hammond company has met with immediate public acceptance. This monophonic or melody instrument, the Solovox, based on the developments of George, Hanert and Hammond, employs a cascaded group of vacuum tube oscillators locked into frequency-halving relation. The locking signal is provided by means of a vacuum tube "master" oscillator, the frequency of which may be changed in steps corresponding to the twelve chromatic notes of the highest octave. The cascaded "slave" oscillators automatically follow all changes in the frequency of the "master" oscillator in octave intervals. The key-controlled switches have two functions in that they first adjust the master oscillator to the desired note within the highest octave and they also determine the "slave" oscillator from which the output signal is derived. This system has the advantage that the master oscillator has to provide only twelve stable frequency steps from which the frequency stability of the other octavely related notes automatically follows.

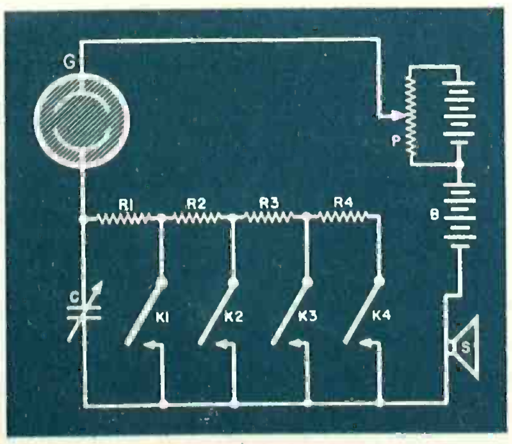
Apart from its circuit, also the practical arrangement and construction of the Solovox are quite interesting. Its present commercial form comprises two units which are only electrically connected. Of these, the larger one contains the power pack, the system of cascaded oscillators, the amplifiers and the speaker. The other includes the keyboard, the volume control and a system of switches for changing the frequency range, the tone color, and to some extent also the type of attack. This second unit is so constructed that it may be mounted underneath the keybed of a piano, with the Solovox keyboard protruding at a slightly lower level in the direction of the keys of the piano. The Solovox keys, while equal in width to those of the piano, are greatly reduced in length, so that they do not interfere with the normal operation of the piano. On the other hand, it is possible to carry a sustained melody with a choice in tone color by operating the short Solovox keyboard with the right hand and at the same time providing piano accompaniment for such melody with the left hand on the piano keyboard. Although the range of tone colors obtainable with the Solovox is rather limited and some of the tone colors are not fully satisfactory musically, this was no serious obstacle in the way of practical application on a large scale in view of the relatively low cost of the instrument, and as a result of the interesting musical possibility given by the ingenious combination of a traditional percussion type instrument with a radionic melody type instrument producing sustained notes.

All of the radionic musical instruments described in the foregoing start out from sustained oscillations of substantially constant amplitude and consequently produce sounds in general, similar to those of the string and wind families of traditional musical instruments. Bethenod's Pianoharp, on the other hand, represents an interesting attempt toward producing damped oscillations, the amplitude of which gradually decreases to zero a shorter or longer time after their initiation. An electrical oscillation of this type, when converted into sound, is imitative of the percussion type of musical instruments, such as the harp, the piano, the guitar, etc. The Pianoharp presents interesting musical possibilities, although this instrument has never become commercial, presumably due to the high cost, large dimensions and other difficulties connected with the construction of low-loss resonant circuits.

The radionic musical instruments discussed so far, whether of the beat-frequency oscillator type or of the audio frequency regenerative type, have the common characteristic of employing resonant circuits to determine the frequency of the oscillations produced. In contrast to this, the class of radionic musical instruments to be described in the following employs relaxation oscillators, that is, oscillators of the type in which the oscillations are produced by periodically building up and breaking down the energy stored in the electric field of a condenser.

Relaxation oscillators have much to recommend them for the construction of radionic musical instruments. They generate oscillations of distinctly non-sinusoidal character, and are particularly adaptable to producing saw-tooth waves and similar waves having a practically unbroken series of harmonics from which the desired ones may be easily selected by simple filter circuits. Their frequency may be readily stabilized by the introduction of small voltages of harmonic or subharmonic frequency. Other important advantages are their great simplicity, small dimensions and substantial frequency range obtainable with small and inexpensive circuit elements such as resistors and condensers.

Fig. 6. The Emicon, a melody instrument.



The first attempt to utilize a relaxation oscillator in a radionic musical instrument was Bertrand's Dynaphon which employs a pair of three-electrode vacuum tubes in the familiar multivibrator circuit as shown in Fig. 4. As is well known, the multivibrator may be considered to be a two-stage resistance-capacity coupled amplifier in which the plate circuit of the second tube V-2 is coupled back to the grid circuit of the first tube, V-1, the oscillatory frequency being approximately $1/(R_1C_1 + R_2C_2)$. The produced oscillations are amplified by two more triodes V-3 and V-4 and are made audible in speaker S. Bertrand, however, failed to make full use of the advantages of this type of oscillator, except for the complex harmonic structure, and even employs a rather crude form of tuning by means of a variable condenser of the rotary type C-2. Therefore, his instrument has never progressed beyond the experimental stage.

The simplest relaxation oscillators employ two-electrode glow-discharge tubes, such as the familiar neon tubes. As is known, only a single resistance and a single condenser are required for an oscillator of this type which excels with its simplicity and compactness even in the family of relaxation oscillators.

The author has developed a whole group of instruments using two-electrode glow-discharge tubes, ranging from simple and inexpensive monophonic instruments to polyphonic instruments and organs of substantial scope. Presumably, the author was the first to utilize the principle of impressing small stabilizing voltages upon groups of harmonically related oscillators, which opened the way for the construction of commercial instruments with excellent frequency stability.

Fig. 5 illustrates the fundamental principle of one of the polyphonic instruments. Essentially, a plurality of glow-discharge tubes G-1, G-2, G-3 are provided approximately tuned to the harmonics, for example octavely, related frequencies f, 2f, 4f by means of RC networks R-1, C-1; R-2, C-2; R-3, C-3. The circuit is so

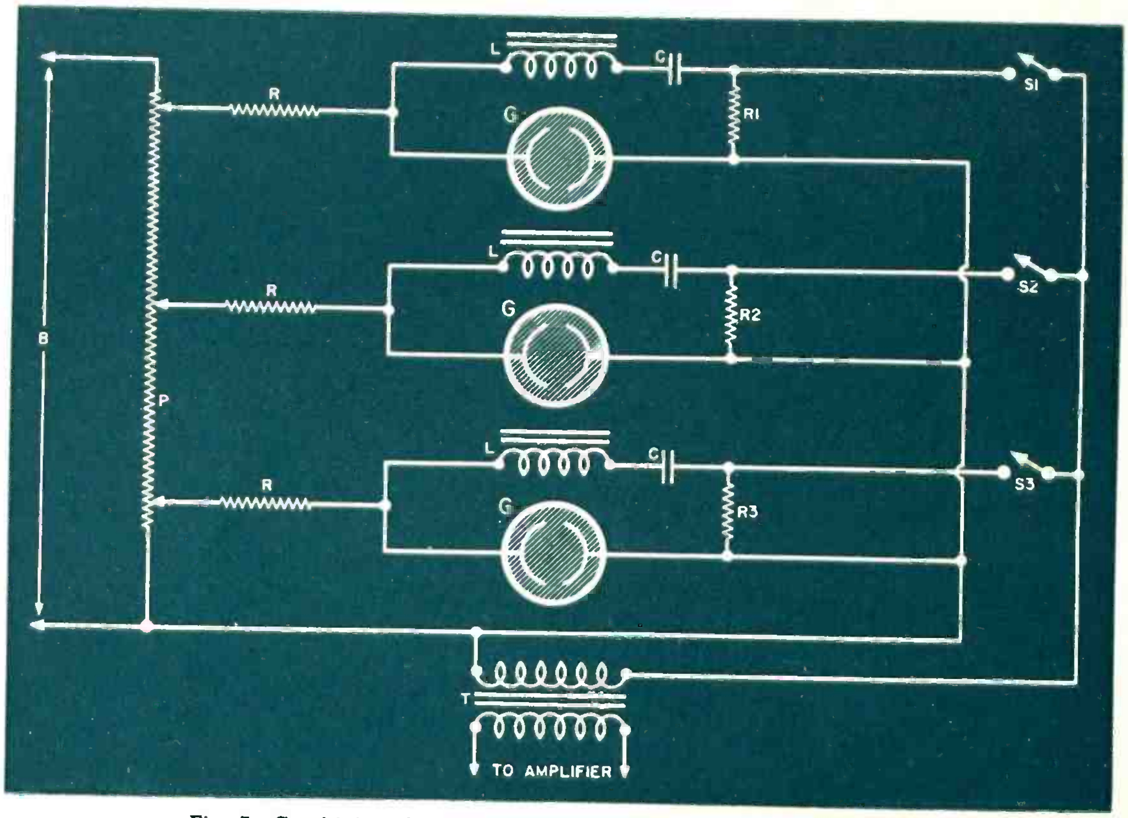


Fig. 7. Combining the relaxation oscillator with a resonant circuit oscillator.

arranged that the resistances are normally disconnected from the corresponding condensers, thereby disabling the oscillators, but may be connected across the condensers by means of switching keys K-1, K-2, K-3. The oscillatory output is introduced into the common load, diagrammatically indicated by a speaker S, although, of course, in actual practice an amplifier is interposed. The accurate frequency relation of the several oscillators is maintained by means of a weak signal of constant frequency f taken from a source A and impressed upon all glow-discharge tubes by means of external electrodes E in the form of a cap or ring provided on the tube. The stabilizing signal of constant frequency may be obtained from an electrically driven tuning fork or from some other similar source. Generally speaking only 12 such sources are required for a complete organ having 84, or more, relaxation oscillators of the described character. This system has the advantage of great simplicity and compactness and also of low cost as a result of the extremely favorable characteristics of the simplest possible oscillators employed.

The author also developed a simple monophonic or melody instrument, the Emicon, which was on the market in 1932-33. The basic circuit of this instrument is shown in Fig. 6. In substance, it is a variation of the two-electrode glow-discharge tube oscillator circuit in which a condenser C is connected in series with a tube G, a source of direct current B and a speaker or other output load S. The frequency of the oscillations is determined by connecting a predetermined number of resistances R-1 to R-4 across the condenser by means of key-controlled switches K-1 to K-4. The relative frequency of the oscillations produced is determined by the ratio of the various resistances, whereas the general pitch of the instrument may be adjusted by varying C or the effective voltage by means of potentiometer P.

Trautwein has developed a monophonic instrument, the Trautonium, which is in many respects similar to the Emicon unit. The Trautonium likewise employs a two-electrode glow-discharge tube which is combined with a condenser and a variable resistance to produce audio frequency oscillations. The novelty in Trautwein's circuit resides in the circumstance that the variable resistance is represented by the plate circuit of a triode of which the grid bias is changed to cause variations in the plate resistance and thereby variations of the frequency within wide limits. The grid bias is adjusted by means of a playing manual in the form of a flexible metallic band making contact upon its depression with different portions of an elongated resistance connected across the filament battery, thereby making effective on the grid corresponding portions of bias battery through a potentiometer. The condenser may be connected by means of switch either across the glow-discharge tube or across the plate circuit of the vacuum tube to change the waveform of the produced oscillations. These oscillations are amplified by means of a two-stage, transformer-coupled amplifier and are made audible through a loud speaker.

Trautwein has also provided an interesting possibility for controlling the harmonic structure of his oscillations. This consists in the provision of a tuned circuit connected into the grid circuit of one of the a.f. amplifier tubes and tuned to a relatively high audio frequency in which a train of damped oscillations is set up by each pulse of the oscillation generator, the rate of decay of these damped oscillations being determined by a condenser providing a controlled amount of feedback.

The application of a triode as a variable resistance, as suggested by Trautwein, has the advantage of being able to use relatively low resistances of a few thousand ohms in the playing manual, formed of closely-spaced turns of a wire having high specific resistance. At the same time, however, the serious disadvantage appears that any slight change in the operating voltages of the triode tube and even small changes in the characteristics of the tube will cause very substantial changes in the frequency distribution along the playing manual. Therefore, Trautwein was unable to produce a keyboard instrument with fixed tuning and was restricted to the so-called type of indefinite tuning with a playing band type of manual. Same as Martenot and Helberger, also Trautwein suggests the arrangement of a dummy keyboard in proximity to the manual, to at least approximately indicate the positions on the playing manual corresponding to the various notes. The impossibility of obtaining sufficient frequency stability for using fixed tuning and a keyboard prevented the Trautonium to acquire any real importance although it was manufactured and sold on a small scale.

To increase the stability of the conventional glow-discharge tube relaxation oscillator, W. E. Kock has developed a circuit which could be considered to be a combination of a relaxation oscillator with a resonant circuit oscillator. A circuit including three oscillators of this character is illustrated in Fig. 7. Each of the oscillators comprises a high resistance R in series with a glow-discharge tube G, and a condenser C effectively connected across the tube through an inductance L. R and C are so determined that together with the other constants of the circuit, a relaxation oscillation of such frequency is produced which corresponds to the resonant frequency of L, C. The fre-

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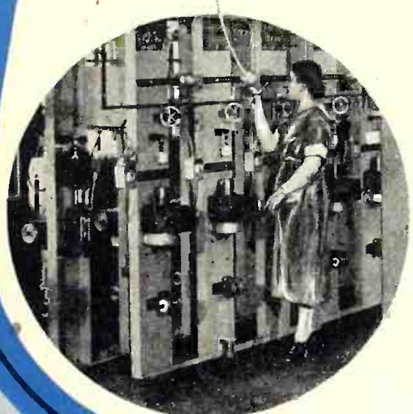
Another Leader in Radio Manufacturing



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Industrial Review

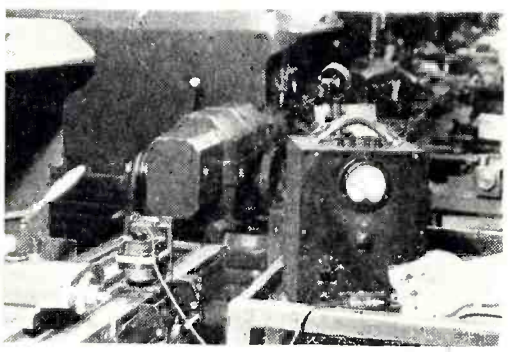
Vibration-Velocity Meter

A GENERAL ELECTRIC electronic vibration-velocity meter was used recently to detect the cause of vibration in grinding machines. The vibration in one machine in particular was causing a large number of rejects.

An investigation made with the aid of the instrument revealed that a set of gears in this machine, apparently in good condition, caused the vibration. Replacing the gears eliminated the difficulty.

It was also found that the meter was valuable for detecting low-vibration areas in a plant, thus facilitating the placing of new equipment in areas where maximum operating efficiency was assured.

The meter, consisting of a vibration pick-up unit and electronic amplifier unit, measures the vibration velocity, together with an integrating



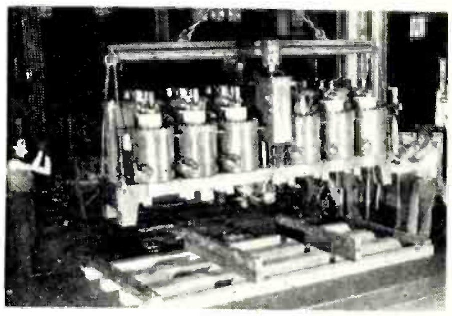
unit, vibration displacement. The amount of vibration can be analyzed graphically by the use of an oscilloscope fed by the amplifier.

* * *

Mercury Arc Rectifier

CONVERTING alternating current supplied by power lines to direct current required in the new Kaiser steel mill at Fontana, California, will be the function of the illustrated 1500-kilowatt mercury arc rectifier. With two 1000-kilowatt G-E rectifiers, one already shipped and another now under construction, this rectifier will convert power for auxiliaries including table rolls, levelers, conveyors, and other equipment in the Kaiser plant.

Mercury-arc rectifiers were used even before the war in aluminum, chemical, and steel mill plants and are now being widely applied throughout war industry. Because they require less critical material and can be produced in shorter time than rotating equipment they are increasing war production. The basic units of the rectifiers are themselves electronic de-



vices in which the unique unidirectional properties of mercury vapor are used to change the alternating current to direct current. Thus they change power supplied from the widely used a.c. power-system to direct-current power which is necessary for most electrochemical processes and many industrial operations.

* * *

Industrial Heating

A RECENT report by H. C. Gillespie of the Radio Corporation of America, showed that production operations have been speeded up as much as 100 to 2500 per cent by the application of electronic devices for industrial heating.

The introduction of radio-frequency heating through electronic devices to prepare compregwood propeller blades for molding reduced the time required for the molding cycle from seven hours to three. One electronic device stepped up the soldering of bases of radio condenser cans from 100 cans an hour to 2500.

In addition to soldering and the pre-heating of wood and plastics for molding, radio-frequency heating applied through electronic devices has proved its advantages in terms of improved products and savings of time, space and labor for case-hardening, annealing, and welding of metals, baking paint, tacking plywood, seaming thermoplastic fabrics, drying textiles, and other industrial operations.

One of these electronic devices has been termed the "radio nail" gun, and resembles a small automatic pistol. It projects a charge of radio-frequency current through the top layer of wood to form a bond in glue which has previously been applied between the layers, thus preventing the layers from slipping as they are laid up.

The rivet detonator automatically sends a charge of current into the head of a special rivet, setting off a small charge of explosive which spreads the other end of the rivet on the "blind" side which cannot be reached.

Radio-frequency heating is not only quicker, but also permits closer control as to the area to be heated. It also provides more uniform heating and for many processes is more efficient and more easily adapted to mass production methods.

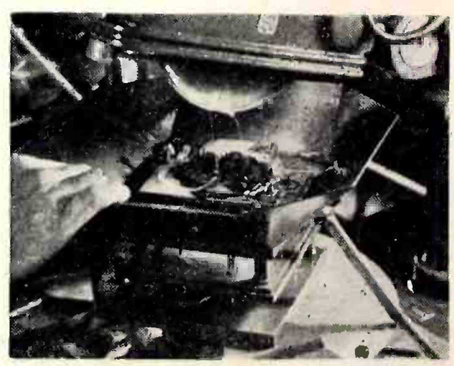
Induction heating has been universally applied to the field of annealing processes. The degree of control can be illustrated by the fact that one end of a metal object can be brought to a white heat while the other end remains cool. This is an advantage in the manufacture of many machine parts which function best if one portion is case-hardened while adjacent areas remain unhardened. A good example of the desirability of uniform heating throughout a piece of material is found in the pre-heating of plastic materials to prepare them for molding. Heat from conventional sources must penetrate the raw material from the outside, which tends to pass through the desired "tacky" stage and harden before the inside becomes workable. With radio-frequency power, which generates heat within the pre-form itself, the entire piece becomes workable at one time.

Other advantages stem from the fact that radio-frequency heating generates heat in the object treated, with no transfer of heat required. This means that heating of associated elements is unnecessary, there is little heat loss to surroundings, no actual contact with materials to be heated is required, corrosive gases are eliminated, and surfaces of material being worked are not adversely affected.

* * *

Crystal Cutter

NEW cutting and salvage methods, employed by the John Meck Industries, are helping to relieve the serious shortage of large, clear quartz



crystals used to make oscillator plates for military transmitters and receivers, electronic devices, and artillery range-finding. (*Continued on page* 31)

Personals

JAMES G. KELLOGG has been elected President of the Kellogg Switchboard and Supply Company.

He is the son of the Founder of the Company and has been instrumental in establishing the organization as one of the leading telephone and communications equipment manufacturers in the country. After four years of retirement, Mr. Kellogg returns at a time when his experiences in company affairs will be most useful.

I. R. WEIR has been named Assistant to the Designing Engineer of the Transmitter Division of General Electric Company's Electronics Department, according to C. A. Priest, Division Manager.

In this capacity, Mr. Weir will assume complete responsibility for the engineering and drafting activities at the Syracuse Plant of the Division, where he will be located. Mr. Weir has been with G-E since 1921.

H. GREGORY SHEA has been appointed Production Manager of the Electronic Corporation of America.

Mr. Shea brings to the organization many years of experience in the management and engineering fields. His last important connection was as Assistant Superintendent of Methods and Planning, Chief Industrial Engineer and Special Assistant to the Works Manager at the Utah Ordnance Plant of the Remington Arms Co.

LIONEL M. SEARLE, for the past year, Manager of the Monroe Street Plant of the Simplex Radio Division, Philco Radio Corporation, has been recently appointed Manager of the entire Division.

Mr. Searle, a graduate of Drexel Institute of Technology, joined Philco in 1933 as a mechanical inspector. He was later cost estimator for all Philco products and later became Assistant Plant Manager at Sandusky.

JOHN A. HUTCHESON has been appointed Associate Director of the Westinghouse Research Laboratories.

Mr. Hutcheson has been known for developing many new secret devices used in military radio communications. His immediate assignment at the Laboratories will be to direct wartime micro-wave research; however, his scope of responsibility will include all other phases of research engineering.

ALBERT G. KOBER, Assistant to the Advertising Manager, Stromberg-Carlson Company, died suddenly on October 5th. Starting in the Factory as an assembler, he gained experience in all branches of the company's activities. Mr. Kober's fine personality will be greatly missed by his associates.

Frequency Changers

(Continued from page 11)

A solution to this problem has been invented by E. L. Kent (U.S. Pat. 2,274,370). It utilizes the arrangement of Fig. 5, where the complex wave, the frequency of which is to be reduced, is applied to the No. 1 grid of a multi-grid tube such as a 6SA7, while the No. 2 control grid is excited from a pulse oscillator.

The output of this oscillator has the wave-shape indicated at A in Fig. 6, while the complex wave shifted by the device is graphically represented by curve B. Referring again to Fig. 5, R_1 is a suitable load resistor across which the output wave-form appears while C_2 is a by-pass condenser serving the usual frequency discrimination function. The 6SA7 is biased beyond cut-off to such an extent that plate current does not flow during any part of the cycle of either the pulse wave or the complex wave. When, however, they both appear together, the sum is enough to carry the characteristic into the plate current region, and a pulse of current will accordingly flow each time there is a voltage pulse on one of the grids, and the magnitude of the plate current pulse will be a function of the shape and size of the complex-wave envelope. This is graphically shown in Fig. 6. The condenser C_2 (Fig. 5) by-passes the high-frequency components in the output, while allowing the reduced wave-form to appear across a load resistor. Each of the input pulses has its effective length determined by the recurring waveform and becomes an element in the output wave-form. This system is useful where a complex wave must be reduced to a lower value without altering the envelope.

There are, of course, applications where it would be helpful, if one could conversely change a low-frequency complex wave to a higher frequency value without altering its wave-form. This, however, is a considerable problem as it involves foreknowledge of an event that has not yet occurred. Simple frequency-multipliers work because we know that the wave-shape can be sinusoidal, and it is only necessary to rigorously establish a ratio between the input and output frequencies. One of the important things, however, about a complex wave-form is that we have no prior knowledge of its shape. We can reduce its frequency, because we are projecting an event that has occurred upon a stretched-out time axis. The writer is not aware of the converse of this operation.

★ ★ ★ ★ TECHNICAL BOOKS ★ ★ ★ ★

"GRAPHICAL CONSTRUCTIONS FOR VACUUM TUBE CIRCUITS," by Albert Preisman, E. E. Published by *McGraw-Hill Book Company, Inc.*, New York and London. 234 pp. Plus index. Price $2.75.

This book presents a graphical method of solving problems of the non-linear type and applies this method to vacuum tube circuits. In the first chapter, the author indicates the generality of the non-linear problem and emphasizes the special case which the linear problem plays in the solution of vacuum tube circuits. Later chapters deal with specific graphical constructions and apply them to such problems as "Distortion Products in a Pentode," "Effect of Variation in Load Impedence," "Non-linear Resistance with Reactive Loads" and "Balanced Amplifiers."

This book is not a complete exposition on graphical methods, but it is a contribution to the solution of non-linear circuits and should give the reader a fundamental grasp of this important subject.

"REFERENCE DATA FOR RADIO ENGINEERS" published by the *Federal Telephone and Radio Corporation*, 67 Broad Street, New York City. 200 pp. Price $1.00.

This is a compact, convenient radio handbook of fundamental reference data presented as an aid to radio research, development, production and operation. The material contained in this book provides for the requirements of the engineer as well as the practical technician, and readers will find it useful both in the laboratory and in the field.

"PATENT LAW FOR CHEMISTS, ENGINEERS AND STUDENTS" by Chester H. Biesterfeld, B.ch.E., M.P.L. Published by *John Wiley & Sons, Inc.*, New York City. 22 pp. plus index. Price $2.75.

In presenting the various subjects of the patent law, an endeavor has been made to explain the basic principle or rule underlying the subject under discussion, and to illustrate by the citation of leading cases and by quotation therefrom of pertinent sections. To this end, considerable time was devoted to an analysis and classification of the decisions on certain subjects in order to present them according to the principles they support. Those who do not possess a professional training in law, but who have frequent occasion to acquire a detailed understanding of some proposition of the patent law in connection with their work, will find it helpful to have within convenient reach and explanation of the subject of inquiry together with pertinent quotations from the decisions. Especial attention has been given to the inclusion of recent decisions of the courts bearing on the various subjects treated, so that the reader may have the benefit of current legal opinion. The consideration of the older cases has been omitted where it appeared that they would not assist the reader in ascertaining present legal trends. This is particularly so in respect to invention, which has undergone quite a transformation within the past five or six years with the result that the standard of invention is now materially higher than a decade ago.

A reader interested in television, fascimile and electronic patents will find many valuable legal aids. This is particularly important since the courts have been holding invalid about 80 to 90 per cent of the patents coming before them in recent years.

"HYPER AND ULTRA-HIGH FREQUENCY ENGINEERING," by Robert I. Sarbacher, Sc.D., and William A. Edson, Sc.D. Published by *John Wiley & Sons, Inc.*, New York City. 632 pp., plus index. Price $5.50.

This book is intended for use by senior students of electrical engineering, and by men with equivalent training who have had at least one course in radio engineering. Mathematical complexity has been avoided, and wherever possible each problem has been approached from fundamental physical principles. Nevertheless, a considerable amount of mathematics is necessary to permit logical development of various phases presented in the book. It may be noted that certain of the mathematical sequences are rendered formidable in appearance by the inclusion of intermediate algebraic steps which are omitted in many publications. The inclusion of these additional equations should facilitate a complete understanding of the development.

Although no definitely established frequency limits are associated with the terms hyper frequency and ultra-high frequency as applied to radio

(*Continued on page* 35)

Heating of Plastics

(*Continued from page* 4)

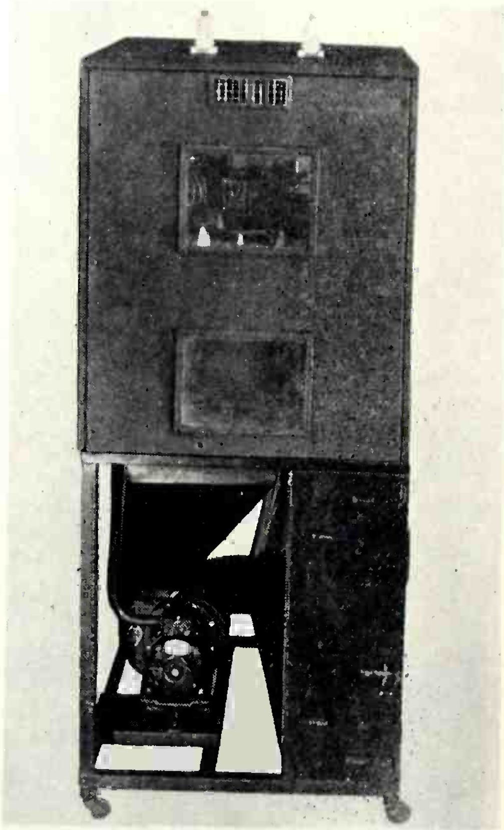
condition was finally eliminated by using two separately tuned condensers in the plate tank circuit. This allowed each tube to be independently tuned to the same frequency. If a split stator condenser with the rotor on the same shaft is used, great care must be exercised to make sure that each tube circuit is symmetrical.

Radio frequency output was controlled by the variable condenser across the pickup coil in the earlier circuits. Because of the de-tuning effect of this type of control, a variable transformer was placed in the primary lead of the power supply plate transformer. With a setting of 117 volts of this variable transformer, the oscillator could be adjusted for maximum load at the proper frequency. If less power was wanted, the voltage could then be reduced without appreciably de-tuning the tank circuit.

At times, the automatic molding machine would stop, and if the operator was absent when this occurred the powder in the pre-heating tube would become too hot and clog. To avoid this, a switch in series with the plate power transformer was installed. When the molding machine stops, this trips the plate supply switch which, in turn, cuts off the plate current.

The component parts of the oscillator were mounted on a chassis made of seasoned hard wood. This was used

Fig. 5. Side view of high-frequency unit with centrifugal blower, for air cooling of the power oscillator.



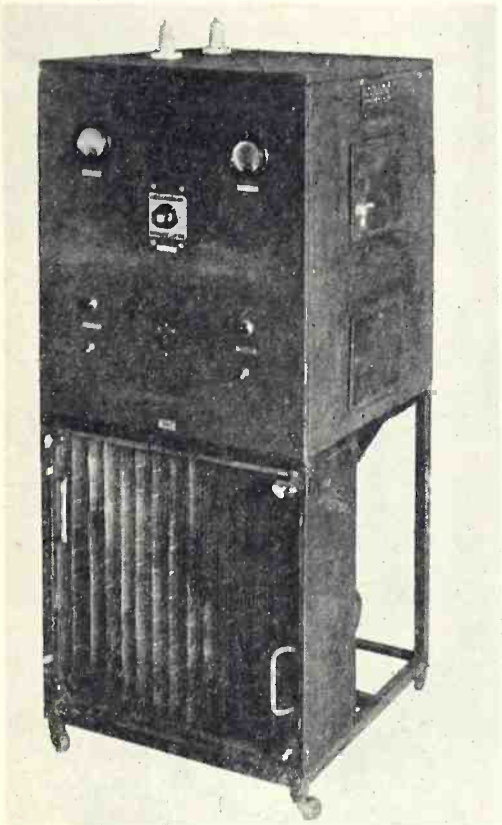


Fig. 6. High-frequency unit with voltage control and d-c milliammeter mounted on front panel.

to reduce the absorption of r.f. energy, which, in turn, would increase the overall efficiency. Coupling the electrodes to the tank circuit was accomplished by using a semi-flexible No. 8 copper cable 42" long, as shown in Fig. 1b. This length is for an operating frequency of 25 megacycles. The variable condenser across the plate tank circuit is used to vary the frequency when required to adjust for proper heating effect when variations in the dielectric of the molding materials are encountered. The power supply was mounted on a metal chassis with holes punched in it similar to guard metal. Taylor 866 tubes are used as a full wave rectifier.

The cabinet that houses the oscillator and power supply, as shown in Figs. 5 and 6, is equipped with a blower and an air intake filter. A filter is necessary because of the dust usually found in a molding department. The air is blown through the oscillator chassis on the second shelf and is emitted from louvers in the top of the cabinet, which automatically close when the blower is not in operation.

Enough evidence has been accumulated to prove that electronic preheating is the only practical method for use with automatic molding machines; and that coupling this development with improvements in plastics, preforming and molding equipment, will lead to production speeds which seem impossible today.

Industrial Review

(*Continued from page* 26)

Shown in the photograph is a newly improved diamond saw, developed to save cutting waste of scarce Brazilian quartz crystals. This new saw permits single crystals to be sliced into hundreds of slim wafers.

Now, hundreds of thousands of crystal oscillator plates can be made from quartz formerly junked. Finer cutting saws make it possible to utilize the good portions of a lower grade quartz that, before, accumulated into waste piles in Brazil.

* * *

Wave Meter

PHILCO engineers have recently developed a wave meter that has extreme accuracy for wide variations in temperature and humidity. The basic principle used in the design of this meter has been the introduction of a thermostatic control in the radio circuit of the wave meter. This control is a self-compensating device in which the effective length of the wire in the control coil actually would be increased or decreased as the temperature varied. The principle depicted is similar to that used in thermostats in automatic heating.

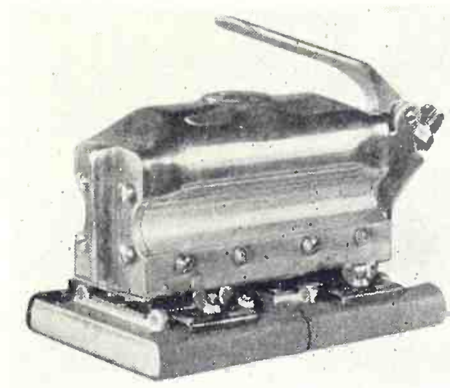
As a result of this development we have meters that can now be produced and depended upon for exactness and accuracy, to align radio equipment used in our airplane and tanks on fighting fronts throughout the world.

* * *

Hand Sander

DESIGNED and built for all practical hand sanding and finishing operations, the Sundstrand Sander, Rockford, Illinois, is now available in a light-weight, hi-speed Model 1000.

This smaller and lighter machine weighing less than 6 lbs., has a speed of 3500 oscillations per minute, and can be equipped



with different types of sandpaper attachments for large or small, wide or narrow, flat or curved abraiding surfaces on metal, wood, plastics, or composition.

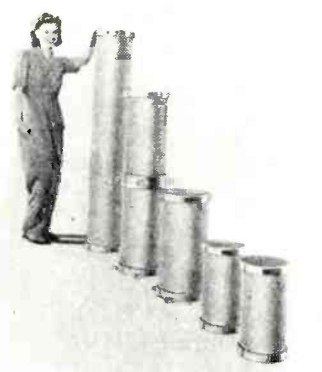
Operation of the machine is obtained with pad movements started and controlled by a palm lever fitted at top of the machine housing. No turning of "on" or "off" switches is required. When machine is gripped to operate, the reciprocating action of pads starts. Upon release, the machine automatically stops.

This sander is free from vibration. Opposed pad action and balance of moving parts eliminate all vibration and improves the qualities and uniformity of the finished product.

NEW PRODUCTS

HIGH-VOLTAGE BAKELITE-CASED TUBULAR CAPACITORS

New type of high-voltage capacitors for X-ray, impulse generator and other intermittent d-c or continuous a-c high-voltage applications such as indoor carrier-coupler capacitors, test equipment and special laboratory work, are announced by *Aerovox Corporation* of New Bedford, Mass.



These types of capacitors are oil-impregnated oil-filled with Hyvol vegetable oil. This means smaller capacitor size and minimum weight consistent with safety in high-voltage operation. The capacitors are built with adequately insulated and matched sections of uniform capacitance, connected in series. Equal voltage stresses are maintained for all sections, with a uniform voltage gradient throughout the length of each capacitor. High-purity aluminum foil with a generous number of tab connectors provides high conductivity with low inductive reactance. Capacitor sections are dried and impregnated under high vacuum in a closely-controlled long cycle. This eliminates voids and also provides for high insulation values and lower losses.

The case is of special laminated bakelite tubing, protected by a high-resistance insulating varnish for high dielectric strength and maximum safety from external flashover. Long creepage path between terminals means an exceptionally conservative and safe rating for these units. Dependable operation and long service life is assured at rated voltages and ambient temperatures up to 65° C.

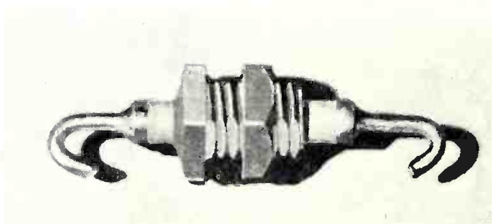
The terminals are two-piece cast-aluminum end caps with bakelite-treated cork gaskets, which are locked in to provide leak-proof hermetic sealing. Caps are available with mounting feet for space-saving assemblies in series, parallel or series-parallel arrangements. Also obtainable with plain end caps. Produced by the *Aerovox Corp.*, New Bedford, Mass.

BUSHING MOUNTED CAPACITORS

Centralab's new Bushing Mounted Capacitors are identified as type 817 and are used in high-frequency circuits where a capacity ground to the chassis and a "lead thru" is desired.

The ceramic capacitor tube is plated internally and externally with silver and then with copper. The tube is a snug fit in the brass bushing and the external capacitor plate is soldered to the bushing. The tinned copper wire is also a snug fit inside the capacitor tube and is soldered to the internal plate. The entire unit is wax impregnated after assembly. Cadmium-plated brass mounting nut, 5/16" hexagon, *Centralab* part 395-239 can be furnished if required.

Dimensions, capacitance, temperature coefficient and voltage breakdown are all closely related and changing any one of these details will change the others. The unit in current production is part 817-001. Capacitance is 55 μμfd. plus or minus 10%. Temperature coefficient is —.00052 μμfd./μμfd./° C., test voltage is 2000 volts d.c., working voltage is 1000 volts d.c.

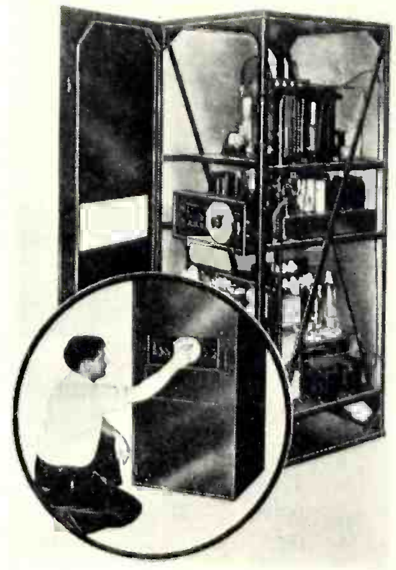


Other capacities and sizes can be manufactured if the quantity needed, justifies the tooling of special parts. Manufactured by the *Centralab Div. of Globe-Union Inc.*, Milwaukee, Wisconsin.

VARIABLE-FREQUENCY ELECTRONIC GENERATOR

This unit was developed to fill the need for a versatile source of power, especially for engineers requiring test power at various loads through a wide-frequency range. Research laboratories, and an increasing number of manufacturers, in the field of electronics, find this electronic generator capable for delivering power with good regulation and waveform over a frequency range of 300 to 3500 cycles.

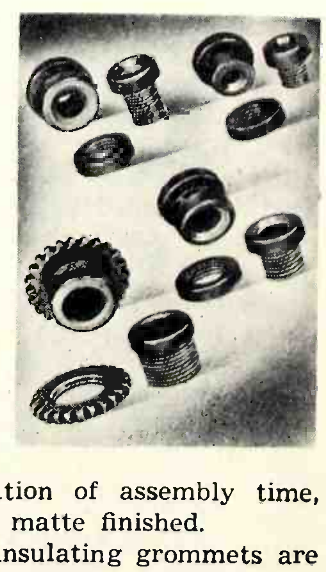
This electronic generator includes a variable-frequency oscillator, followed by several driver stages. The output stage employs a pair of 833-A tubes in Class B. Because of the high impedance of such a power source, the regulation of generators of this type is quite poor, ordinarily. CML 1400 overcomes this difficulty by means of a special control circuit which maintains output voltage at a substantially constant level.



Descriptive bulletin available from the manufacturer, *Communication Measurements Laboratory,* 120-24 Greenwich Street, New York.

PLASTIC INSULATORS

Of special interest to production engineers seeking to cut down assembly time operations, *Creative's* new line of 100% phenolic plastic insulating grommets offers many important advantages. These new grommets, available in four standardized sizes, have been developed especially for use by radio, motor and electronics manufacturers. Holes are concentric, with all corners chamfered, avoiding wire chafing. All threads are clean and lubricated. To promote easy gripping and conservation of assembly time, all parts are matte finished.



Creative's insulating grommets are

(*Continued on page* 36)

Calibration Standard

(*Continued from page* 18)

employed in this lamp, is nearly uniform, no correction is necessary for most practical purposes. The transmission of the fused-quartz envelope of the lamp must be taken into consideration, however, when a phototube has its major response in the short wavelengths, for example, a tungsten or tantalum phototube in a quartz or special ultra-violet transmitting glass envelope.

Inasmuch as this tungsten-in-quartz light-giving device is calibrated by a single measurement of the average filament temperature, its emission of ultra-violet rays is computed easily and maintained constant by controlling the lamp's voltage. Due to heat conduction along the filament to the supporting hooks within the light-emitting unit, and because of variations in the thickness of the filament and absorption of rays from other parts of the filament assembly, inevitably there are always changes in the temperature of the different sections of the filament. Therefore, for this lamp, the average temperature is obtained by noting the color temperature of the entire visible radiation and reducing this figure to the real temperature.

Stair and Smith contemplated the use of a ribbon wire rather than a round-wire filament, as a means of reducing the end and loop-cooling effects, but because of obstacles in maintaining different sections of the filament in the same plane, the round wire was given a unanimous vote in view of the stability of the radiation received by the radiometer. The end cooling effects were cut down to a minimum by having the shields embrace one-fourth to one-half inch of the filament ends and loops. The heat variations in different parts of the filament were curtailed by wider spacing of the filament loops.

Photoelectric cells possess so-called long wavelength "tails," according to the Bureau of Standards, in their relative spectral-response curves. These are not detected in the standard spectroradiometric calibration work, but in use of phototubes the resultant errors may be large. In the use of this lamp, however, these wavelength "tails" are not only exposed, but the extent of their effect is measured. Thus, when the lamp is used in conjunction with a set of calibrated filters, the photoelectric cell assumes importance in precision work.

According to Stair and Smith, by measuring the integrated transmissions of a set of calibrated filters with

TABLE 3

The data for tube A was taken from Table 2, and shows close agreement between observed and calculated transmissions. The data for tube B shows a large discrepancy, although the response curve was obtained with great care on a good spectroradiometer. The calculations marked 1 were made upon the basis of a smooth spectral-response curve drawn through the spectroradiometrically observed points. Calculations 2 were made upon an adjusted curve (see Table 4). Tube B appeared to have a slight amount of "fatigue," which probably accounts for part of the discrepancy between the calculated and observed filter transmissions.

Filter	Phototube A (no filter)		Phototube B (no filter)			Phototube B (Nillite filter)		
	Obs.	Calc. 1	Obs.	Calc. 1	Calc. 2	Obs.	Calc. 1	Calc. 2
Corex D	59.0	57.9	38.2	24.9	34.0	75.6	63.5	75.1
Nillite	31.9	32.0	19.0	6.7	15.4	53.8	31.4	53.8
Barium Flint—1	14.8	15.3	8.8	1.2	7.6	31.3	9.1	34.8
Barium Flint—3	5.8	4.6	3.3	0.1	3.1	13.4	1.0	15.6

Results of comparative tests of two phototubes for agreement between calculated and observed filter transmissions.

this lamp as a source (calculating these transmissions of the same filters from information of their spectral transmission) the spectral-energy emission of the lamp, and the spectral response of the phototube (based upon an arbitrary curve drawn through the values for the wavelengths at which the response was determined by a radiometer) the shape of the phototube response curve may be changed until the observed and calculated transmissions are in accord.

Practically, the number of filters may be increased by employing combinations of each filter with the one possessing the nearest long (or short) wavelength cut-off. In some instances, however, more remote combinations of filters may be used advantageously. This is doubly true, where filters, having bands of selective absorption, are used in evaluating radiation over a long wavelength range of the spectrum. Corners may be cut, so to speak, and labor conserved by employing a combination filter instead of calibrating a new one, if the combination gives the results sought.

(*Continued on page* 34)

Washington Briefs

INDUSTRIAL ADVISORY COMMITTEES

The War Production Board has recently announced the formation of the following Industry Advisory Committees:

MICA CAPACITOR CONSERVATION COMMITTEE

Government Presiding Officer: E. R. Crane; Committee members: G. M. Ehlers, Centralab, Inc., Milwaukee, Wisconsin; Jack Davis, Galvin Manufacturing Co., Chicago, Illinois; T. M. Gordon, Radio Receptor Company, New York, New York; M. R. Johnson, General Electric Company, Bridgeport, Connecticut; Bryon Minnium, Erie Resistor Company, Erie, Pennsylvania; Dorman D. Israel, Emerson Radio & Phonograph Corporation, New York, New York; Herbert L. Spencer, Bendix Radio Corporation, Baltimore, Maryland; F. E. Hanson, Western Electric Company, Kearny, New Jersey.

COATED ABRASIVE COMMITTEE

Government Presiding Officer: Franz T. Stone; Committee members: George Balcom, Abrasive Products, Incorporated, South Braintree, Massachusetts; James Jackson, Mid-West Abrasive Company, Detroit, Michigan; A. G. Bush, Minnesota Mining & Manufacturing Company, St. Paul, Minnesota; Charles Knupfer, Carborundum Company, Niagara Falls, New York; H. M. Elliot, Behr-Manning Corporation, Troy, New York; George Manning, Armour & Company, Chicago, Illinois; E. B. Gallaher, Clover Manufacturing Company, Norwalk, Connecticut; Austin M. Porter, Wilmington Abrasive Works, Incorporated, Wilmington, Delaware.

RADIO TUBES

More than a half a million radio receiving tubes for home radio sets were made available for users recently by the Radio Division of WPB.

A total of 576,613 radio receiving tubes is in the possession of the Phillips Export Corporation, P.O. Box 69, Grand Central Annex, New York, N. Y. These tubes had originally been held for export, but after discussions between representatives of the Foreign and Domestic Branch of the Radio and Radar Division and officials of the Phillips Export Corporation, it was decided that WPB would authorize sale of the tubes without restriction to the domestic market.

Distributors or dealers purchasing these tubes will be governed by Limitation Order L-265 in their resale. The authorization allows any person to receive tubes from the Phillips Export Corporation without restriction as long as they are to be used domestically.

These tubes are types that are generally used in home radio receiving sets. The number of tubes now available in the nation for maintenance and repair of household sets is below actual needs, and the release of these half-million tubes is a step towards making more tubes available for civilian replacement uses.

BLUE NETWORK SALE APPROVED

The Federal Communications Commission approved the purchase of the Blue Network by Edward J. Noble from the Radio Corporation of America.

At the same time, the Commission ordered that Regulation 3.107 prohibiting multiple ownership of networks serving substantially the same area be made effective six months hence. This regulation, adopted May 2, 1941, had been suspended indefinitely to make possible the orderly sale of the Blue without a deadline which would unduly depress the price.

The Commission noted that its investigation into chain broadcasting established that the ownership of two networks by a single organization operated as a restraint on competition, handicapped the Blue Network.

The transfer of the Blue will result in four independent nationwide networks. "This," the Commission declared, "will mean a much fuller measure of competition between the networks for stations and between stations for networks than has hitherto been possible. In addition, the transfer should aid in the fuller use of the radio as a mechanism of free speech. The mechanism of free speech can operate freely only when the controls of public access to the means of a dissemination of news and issues are in as many responsible ownerships as possible and each exercises its own independent judgment."

The Commission also pointed out that at a public hearing on September 20, it appeared that under present practice which is quite general in the industry requests for the sale or furnishing of time tend to be disposed of on the basis of rules-of-thumb and fixed formulas. "Mr. Noble's commitment to consider each request with an open mind on the basis of the merits of each request and without any arbitrary discrimination is, in our view, the type of discretion which all licensees must retain under the Communications Act," the Commission asserted. "Only under such flexibility is the fullest utilization of radio in the public interest made possible."

Calibration Standard

(*Continued from page* 33)

In this method of finding out the response of a photoelectric cell, the entire electrode is completely and uniformly irradiated so that any local variations in the relative spectral response are averaged into the ultimate response curve for the cell as used in practical work. This is said to be of great value, inasmuch as the cells commercially manufactured rarely have a cathode of uniform surface. Differences in thickness of the sensitive layer or the presence of impurities alter the spectral response of one area of the receiving surface with respect to an adjoining area of the same photoelectric cell.

Once having evaluated the spectral photoelectric response and the trans-

Adjustment of phototube spectral response.

TABLE 4

The values listed below indicate the adjustment in the relative spectral response of phototube B (Table 3) required to give filter transmissions which approximate the observed values, when using the tungsten-in-quartz lamp and calibrated filters (Table 2).

Wavelength	Spectroradiometrically observed response, curve 1	Adjusted response, curve 2
A		
2600	133	108
2640	121	103
2680	110	98
2720	97	90
2760	85	83
2800	72	72
2840	60	60
2880	48	48
2920	37	37
2960	26.5	26.5
3000	18	18
3040	12	13
3080	7	9.5
3120	3.5	7
3160	2	5
3200	0.8	4
3240	.2	3
3280	...	2
3320	...	1.5
3360	...	1
3400	...	0.5

missions of the filters, the problem of measuring the ultra-violet radiation from a certain source must be investigated. This requires exact information as to spectral quality of this source. If the latter is a temperature radiator—for instance, an incandescent filament lamp of unknown temperature—a smooth curve may be assumed and adjusted to its real relative spectral value through a series of observations and estimations on the filter transmissions. If the source of ultra-violet radiation is discontinuous—for example, a metallic arc—the wavelength and knowledge of the relative intensity of the emission lines are necessary.

Inasmuch as the fused-quartz envelope of this lamp absorbs the long infra-red rays emitted by the filament and sends out some infra-red radiation of extremely long wavelength (characteristic of the temperature of the quartz envelope), this lamp is more readily calibrated (for absolute radiation intensity per unit of wavelength at a fixed position relative to the lamp), by using a 1 centimeter water cell over the thermopile. Phototubes, however, are not sensitive to the infra-red rays, and a water cell is not necessary in the use of the lamp with them. If the sensitivity of the photoelectric cell is restricted to a narrow range of the spectrum—for instance, when employing two titanium tubes—extra filters may be employed to assess the limited range of the spectrum of the lamp radiation which the particular phototube is sensitive. Inasmuch as the relative emissivity of tungsten over the spectral coverage from 2,300 to 15,000 angstroms is an unknown quantity, it is advisable to limit the range of calibration of this lamp to the amount to which the phototube responds.

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NOTE—*NBS (above): National Bureau of Standards; BS: Bureau Standards.*

Technical Books

(*Continued from page* 30)

communication systems, frequencies above about 30 megacycles per second are generally referred to as ultrahigh frequencies. Originally no upper limit was associated with this term. The term microwaves is sometimes used to identify the band of frequencies beyond those known as ultrahigh. These wavelengths cover the range from approximately 3 centimeters to 30 centimeters. We may, therefore, consider the ultrahigh-frequency band to cover frequencies lying between 30 and 1,000 megacycles per second, and the hyper-frequency band to embrace those of 1,000 to 10,000 megacycles.

In treating problems arising in hyper-and ultrahigh-frequency engineering, the ordinary low-frequency circuit theory is inadequate, and the more general electromagnetic theory is required. Since the usual electrical curriculum does not emphasize general electromagnetic field theory, the first three chapters of this book serve to review the subject. They follow the standard plan employed in most textbooks and treatises.

With the knowledge of the electromagnetic field equations and the laws of reflection and refraction at boundaries the student is prepared to study the propagation of waves in various types of enclosures and guides as explained in the subsequent chapters.

"SOLAR RELATIONS TO WEATHER," by H. H. Clayton, two volumes. Published by the *Clayton Weather Service,* 1410 Washington Street, Canton, Mass. Vol. 1, 99 pp. plus index. Vol. 2, 432 pp. plus index. Price $3.00 each.

Mr. Clayton has occupied the positions of meteorologist at Blue Hill Observatory, local Forecast Official, U. S. Weather Bureau, Forecaster in charge of Forecast Division, Argentine Weather Service, and Associate Research Assistant, Smithsonian Institution. These offices have given him a wide experience in weather conditions in different parts of the world. These volumes give the results of more than sixty years of research in world-wide weather conditions and their relation to solar changes. They also contain studies of the relation of solar changes to magnetic electric and radio conditions. Every student of the weather, aeronautics, and radio should read these stimulating researches which have opened the way to long range weather forecasting.

Nomogram Construction

(*Continued from page 15*)

There is one other type the writer feels is very interesting, the grid nomogram. If an equation containing four variables can be put into the determinantal form of the straight line but such that one row contains two variables, the other two rows being of the form of one variable, it may be that such a nomogram can represent the relationship between the four variables. For example:

$$\begin{vmatrix} 0 & f(u) & 1 \\ g(v, w) & f(v, w) & 1 \\ 1 & f(t) & 1 \end{vmatrix} = 0 \ldots (48)$$

could represent a grid nomogram, if when viewing w as a parameter, a change in value of w actually gives rise to a new locus of v. It is quite obvious that one may view v as the parameter and obtain loci for w. Thus the space containing the family of v-curves can be thought of as criss-crossed with a family of w-curves.

An example of a grid nomogram should explain away any vagueness in the above description. For a straight solenoid, the self inductance[3]:

$$L = \frac{\mu N^2 \pi^2 d^2}{l} \left\{ \frac{1}{1 + \frac{d}{2l}} \right\} \cdot 10^{-7} \text{ henries} \quad \ldots\ldots\ldots\ldots (49)$$

where μ = permeability, N = turns, d = diameter of solenoid in meters and l = length of the solenoid in meters. Letting $L/\mu = v$, the following constructional determinant obtains:

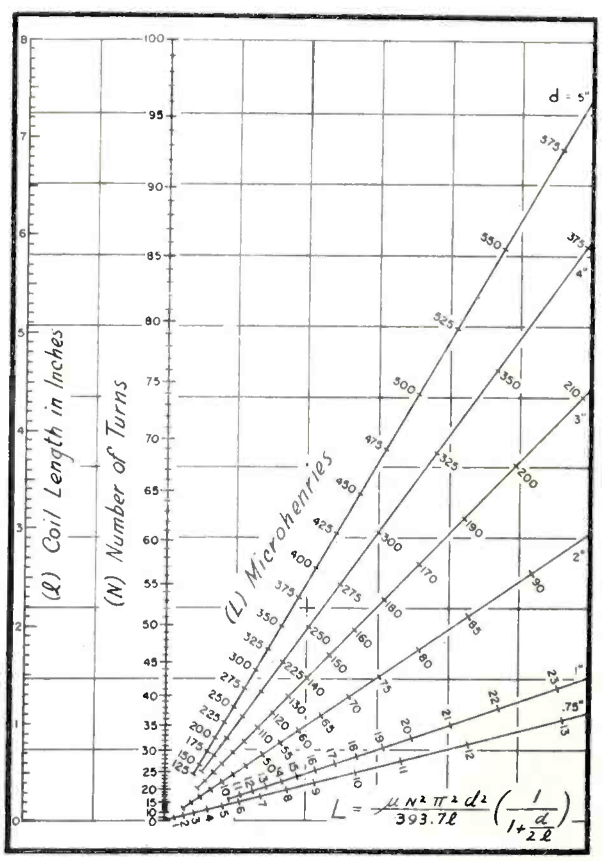

Fig. 7. R-F coil design chart.

$$\begin{vmatrix} 0 & \mu_1 l & 1 \\ \frac{10^{-7}\pi^2 d^2 \mu_1 \delta_3}{10^{-7}\pi^2 d^2 \mu_1 - \mu_3 v} & \frac{\mu_1 \mu_3 v d}{2(10^{-7}\pi^2 d^2 \mu_1 - \mu_3 v)} & 1 \\ \delta_3 & \mu_3 N^2 & 1 \end{vmatrix} = 0 \quad \ldots\ldots\ldots\ldots (50)$$

Considering d as the parameter whereby we shall obtain a family of v-curves,

Thus, all curves will be straight lines, but for a change in the value of d, one will obtain a v-curve with a changed slope.

The ranges for which this nomogram will be constructed are

l = 0 — 8″ or 0 — .2032 meters
N = 0 — 100 turns

The parameter d will range from ¾″ to 5″ or from .01905 meters to .127 meters. It is found then that:

$$\left. \begin{aligned} x &= \frac{\delta_3}{1 - \frac{\mu_3 v}{10^{-7} \pi^2 d^2 \mu_1}} \\ y &= \frac{d \mu_1}{2 \delta_3} (x - \delta_3) \end{aligned} \right\} \quad \ldots\ldots (51)$$

$$\mu_1 = 54.13$$
$$\mu_3 = 1.1 \cdot 10^{-3}$$

In this case we shall pick $\delta_3 = 2$. We cannot pick $\delta_3 = 8$ here, for the v-curves lie wholly to the right of the N-curve. Thus the family of v-curves is given by:

$$\left. \begin{aligned} x &= \frac{2}{1 - 20.5885 \frac{v}{d^2}} \\ y &= 13.53\, d\, (x - 2) \end{aligned} \right\} \quad \ldots\ldots (52)$$

The grid feature is apparent when one connects the points of same v. The space to the right of the N-curve then becomes criss-crossed into a grid pattern.

The foregoing analysis has presented a systematic method of constructing nomograms based upon the geometrical properties of the three-way determinant. The method is obviously one based upon analytical geometry. The advantage and practical value of this procedure become evident upon realizing that the other available methods for constructing nomograms are primarily based upon synthetic geometry.

This is to be expected when considering the development of other fields of science. The analytical method generally follows the synthetic procedure. The analytical method, being more systematic, is far more desirable than the trial and error method.

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New Products

(*Continued from page 32*)

priced from 7c to 10c each, in quantities of 10,000 or over. Samples, price lists, and other data available from *Creative Plastics Corp.*, Sales Division, 970 Kent Avenue, Brooklyn 5, New York.

PACKAGING

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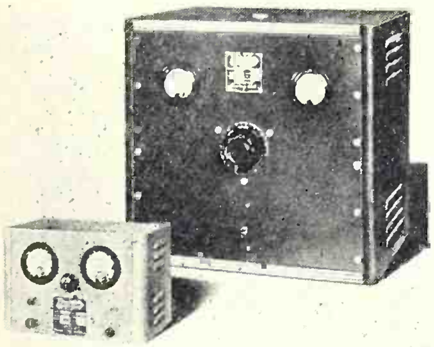

power stations, machine tools, control circuits and other general requirements for 110 volts and up, provided floating or taper charge, multi-rate charging with trickle end rate, and automatic regulated charging.

Musical Instruments

(*Continued from page* 24)

quency may be adjusted by sliders on a common potentiometer P, while the output voltage is taken off across resistors R-1, R-2, and R-3 by means of switching keys S-1, S-2, S-3 feeding into a common output transformer T.

Kock claims greatly increased frequency stability and a greater variety of waveforms from this circuit. More particularly, voltages of substantially sinusoidal wave form may be obtained across condenser C, while voltages of more complex harmonic structure may be obtained from other portions of the circuit. Kock has built organs of an experimental type based on this principle although practical difficulties have been experienced in view of the relatively high cost and substantial weight of the coils which had to be of very large inductance, from 30 to about 1000 Henries.

It was probably for these reasons that, recently, Kock has abandoned his original concept of using oscillators each of which is inherently stable, and adopted the principle of employing stable "master" oscillators and cascaded groups of harmonically related "slave" oscillators, synchronism being maintained between the oscillators by a small voltage impressed from each oscillator upon the next one, as this has been already suggested by Langer, Hammond, George, Hanert, and others. A circuit of this type comprises a "master" oscillator and two "slave" or controlled oscillators approximately tuned to one-half and one-fourth of the master oscillator frequency. The master oscillator is a hot-cathode glow-discharge tube oscillator of a type similar to the well-known sweep oscillators commonly used in cathode-ray tube circuits, with the difference that its frequency is stabilized by the resonant effect of a series resonant circuit. The stages following the master oscillator are unstabilized hot-cathode glow-discharge tube oscillators synchronized by small voltages transferred to their grids through coupling condensers. This type of organ has not been manufactured commercially, but as it appears from Kock's pertinent patent specifications, the principle has been worked out in great detail to obtain a variety of tonal effects comparable to those of a pipe organ.

In the foregoing only the principal systems of radionic musical instruments have been described using purely radionic means, with the full exclusion of mechanical elements, for the generation of electrical oscillations to be converted into musical sounds. In addition, there exist a number of other systems of this type suggested or actually used some time or another for the generation of electrical oscillations in radionic musical instruments. Some of these, such as Burstyn's instrument using a spark gap or a "singing arc" type of oscillation generator are now only historically interesting. Others, like Kucher's instrument using cathode-ray tubes for the generation of oscillatory energy are at a too early stage of their development to be of commercial importance at the present time although this type of instrument may hold great promise for the future of radionic musical instruments.

The radionic musical instruments employing combinations of radionic and mechanical means for oscillation generation, several of which have acquired great practical and commercial importance will be dealt with in a subsequent article.

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Editorial

(*Continued from page 2*)

due to television. People will want to attend the actual event for the glamour and thrill of being with many thousands of people assembled at one place. It is true that television will bring the viewing of these events to many homes, thereby rendering a great public service to those physically or financially unable to attend such occasions, but this will not affect the small percentage of the total populace attending these features.

There is no doubt that the American public anticipates television as the next great American service in the home. Its opportunities are unlimited as a means of advertising as well as providing an entirely new form of entertainment.

—O. R.

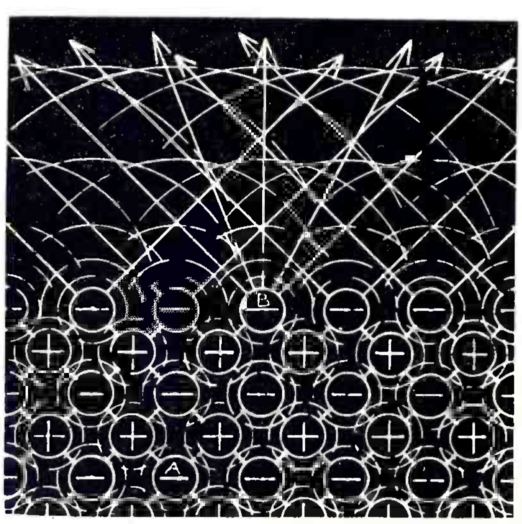
Dust—Dielectrics

(*Continued from page 8*)

face conditions are greatly different from the interior because the surface charges are not symmetrically surrounded by opposing charges. For example, charge A in Figure 5 is surrounded by other fields, while charge B is free of this influence in the outward directions. It follows that the potential energy is greater for the surface layer of charges than the charges within the substance, and electrical activity is directly related to surface area. This explains certain phenomena which are of practical importance in many industrial uses of materials.

An understanding of the *microscopic* activities underlying *macroscopic* characteristics is of great value in selecting materials for specific industrial applications. The increasing knowledge of electro-physico-chemistry gradually eliminates "cut and try" methods, and synthetic substances are rapidly becoming available on a

Fig. 5. Surface energy due to charge distribution in liquids or solids.



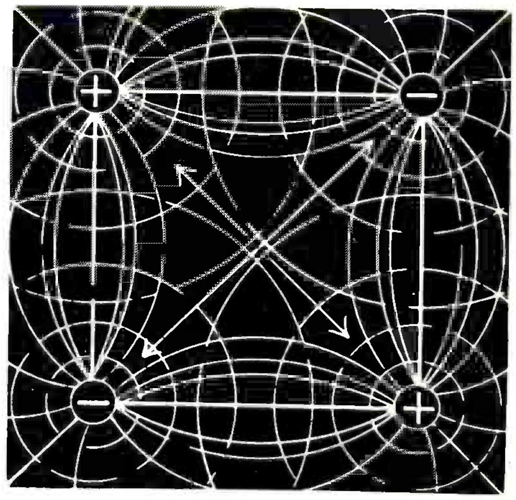


Fig. 4. Electrostatic field of quadrupole.

"characteristics to order" basis. Unfortunately, too few capable scientists are devoted to these investigations, and many industries do not yet realize the extent to which the properties of materials in practical application can be predicted on the strength of available basic information. It is only a decade or so ago that Einstein's relativistic theories of time and space were considered as having value only as mathematical curiosa and to provide material for pseudo-scientific fiction. Today these recently revolutionary viewpoints are accepted as the only logical approach to electro-dynamic theory; practical problems are being solved in terms of the Lorentz space-time transformation and Maxwell's field equations. This paper treats only one small entry in the huge ledgers of information that need to be correlated with industry.

Tripoli, a mineral which is widely used in some industries but little known generally, provides an excellent example of substances with electrically predictable properties not yet fully exploited. This material appears in limited regions of the United States as porous, friable, crypto-crystalline forms of sedimentary silica.

Tripoli is often confused with diatomaceous earth, which is properly termed "tripolite" or "diatomite." No diatoms exist in tripoli. Its geologic origin varies with the location in which it is found, specific impurities and consequent characteristics of its several forms. The free silica content averages 98%, and is not believed ever to fall below 93%. The co-existing substances appearing in different types include Al_2O_3, C_2O, MgO, Na_2O-K_2O, TiO_2, MnO, Fe_2O_3.

Mechanical subdivision down to half a microm does not appear to have any influence on interior structures. X-ray photographs have shown suspension colloids as having diffraction patterns identical with that of coarsely powdered crystals of the same substance. There has been a long-standing question mark with regard to the actual crystal, fibrous or amorphous nature of tripoli. The X-ray diffraction pattern of tripoli is identical with that of quartz, and this has been accepted by some investigators as adequate evidence of identity. Several fibrous microforms, believed to be at least partially amorphous, have quartz X-ray diffraction patterns. These observations indicate a definitely ordered arrangement of basic units but do not necessarily imply that actual crystals are ever obtained.

Electro-magnetic theory as applied to light shows that the index of refraction for increasingly long wave lengths approaches the square root of the dielectric constant, and actual measurements on quartz demonstrate the principle $n^2_\infty = k$. This relationship is not shown here for tripoli since measurements of refraction indices for micro-crystalline structures are calculated on an average basis. The averaged index of refraction for tripoli is approximately 1.537; the dielectric constant is 4.414. It is recognized that the probable error in measurements of dielectric constants for such substances is large, but with careful control of a test series this value has been obtained with considerable accuracy.

Tripoli is extensively used in foundries for parting purposes because of its absorptive qualities in connection with gases. It is elsewhere variously applied as an abrasive, in paint fillers, cements, in the petroleum and many other industries. The possibility of tripoli as a cause of silicosis has been a matter of great concern. This disease results when dust particles of silica are breathed into the lungs. Tripoli is used in the form of dust, some grades being labeled "air-float." Most widely used sizes will pass a 325 mesh screen. Elaborate laboratory experiments using rats and guinea pigs have shown that no variety of tripoli fails to produce the physiologic action associated with silicosis.* 45 samples of various tripoli types on 138 animals showed proliferation in all cases. The interesting fact is that, notwithstanding the capacity of tripoli to cause silicosis, the incidence of that disease among tripoli workers is so low as to be almost non-existent. The circumstance is due, in considerable degree, to the curious surface electrical phenomena of tripoli.

Silica is an unsymmetrical molecule and tripoli structures consist almost entirely of permanent dipole arrange-

** Much of the material regarding tripoli and silicosis appearing in this paper has been derived from a publication by McCord, Meek and Harrold in "Industrial Medicine."*

ments. As a consequence of the unusual exposure of surface area, the potential energy of charges per particle is extremely high. Tripoli is remarkable in activity in the presence of an electrostatic field. A charged hard rubber or glass rod held an inch away will cause the particles to oscillate, jump and rebound to an extent that requires visual presentation to be appreciated. It is largely for this reason that it is difficult to size tripoli by screening processes on cold days and much easier in warm weather. Cream tripoli is much more active in this respect than the rose varieties—it has a lower conductivity and a higher dielectric constant. It is interesting to know that in many trades where abrasives are referred to as "rouge," the rose-colored tripoli is considered preferable. Actual abrasive tests have shown more effective results with the cream type, and this again is due to its tendency to be activated electrostatically and hence cling to the brushes more efficiently.

In the effort to determine finally the pattern of tripoli particles, investigations were made with the petrographic microscope, which makes it possible to rotate the planes of polarized light so as to determine the presence of crystal shapes. First attempts gave quantitative results showing a relatively low percentage of crystal forms. The photographs accompanying this article, which were taken with the RCA Electron Microscope, are believed to be the first visible evidence that the structure of tripoli is not only fundamentally crystalline, but that it exists almost entirely as a finely divided mass of crystals. These crystals appear occasionally in sizes ranging around one-third of a micron, rarely larger, and the great majority are in the order of one-tenth of a micron and smaller. If completely divided, the crystals would exhibit colloidal behavior, and tripoli of this type is actually produced in certain mines. This evidence prompted further investigation with the petrographic microscope using additional controls. Confirmation was finally obtained when it was found possible with the aid of extreme magnification to view rotation of the polarized planes of light with crystal effect through the individual components of the relatively large particle masses.

Interpretation of the Electron Microscope photographs requires that consideration be given to the relative thickness of the large masses in which layer upon layer of interstitially joined tiny crystals are built up. Even with the remarkable depth of focus obtained with the Electron Microscope at this 24,000 magnification, it is not possible to view the larger particles in three dimensions. The edges of these masses, which are more transparent, show clear outlines of crystal chains and spongy clusters.

Along with these photographs is a drawing which projects the indicated structure with greater definition.

The reason that tripoli is not a silicosis hazard in industry is that it is not breathed. It does not readily distribute so as to form suspension in the air. When a suspension does occur, the particles flocculate, form clumps and balls of material and are rapidly precipitated. There is a dual reason for this tendency of particles to cling together. A portion of the result is due to the inter-attractive potential surface energies in the form of dipolar structures, each of which may be considered as a small permanent magnet. The other cause is the tremendous adsorptive coefficient of tripoli for water. The particles adsorb a film of moisture with great rapidity, and when activated in the air, either electrostatically or otherwise, their collisions result in cohesion of the surface films.

Adsorption is a phenomenon about which little is known, except that it is related to surface tensions. The theory presented here is based on radionic principles and is believed to fit the factual conditions. When crystals are dissolved in water, a process somewhat as illustrated in Figure 1 takes place. The permanent dipoles of water cluster around the surface ions of the crystals, and by reason of stronger electrical forces than are exerted in the internal bonding of the crystal, the surface ions are pulled loose. In Figure 7 is a representation of what is believed to happen in connection with adsorption. The dipoles of the water cluster as a result of the same forces that attract them in the dissolving process, and they cling tightly, but they do not have sufficient strength to remove (dissolve) the surface ions which are bound firmly by strong electrical relationships within the crystal. Tripoli will approach hydrostatic equilibrium in a few minutes where other substances require hours, days or weeks. The ability to take up half its weight in water is obviously influenced by the spongy interstices between the colloid-size crystals.

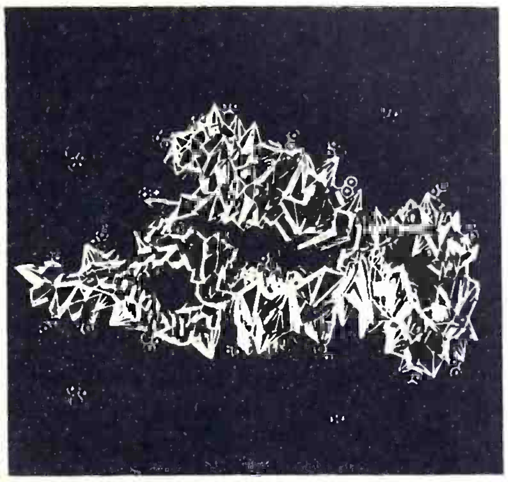
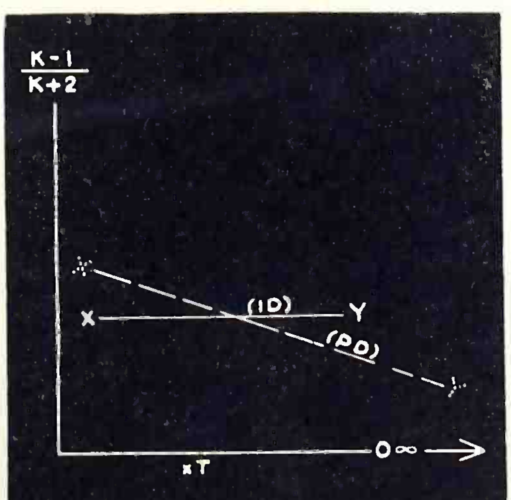


Fig. 7. Depicting a crystal absorbing H_2O.

Fig. 6. Graphically representing, data obtained, for determining the extent the dielectric characteristics of a material depend on permanent and/or induced dipoles.



Although tripoli is already widely used, many of the facts indicated here show possibilities for its application in considerably wider fields. The field of new industrial exploitation for many materials is wide open to the investigator who is willing to trace the fundamental characteristics on which new uses for substances can be projected, who has a sufficiently wide knowledge of industrial requirements and who is blessed with the imagination necessary to correlate his discoveries with practical procedures.

It seems desirable to point the reasons for the title of this paper. Perhaps its primary evaluation is in terms of what is believed to be the first publication of reasonably complete empiric data about the structure of a substance which is small in particle size but large in importance for many industries—Tripoli. The investigation of this mineral required that major consideration be given to factors connected with DUST, DIPOLES AND DIELECTRICS. Further than this, it was intended to draw attention to the inter-relation of the sciences and their fundamental dependence upon the radionic art in the application of accumulated empiric and theoretical knowledge to the problems of industry, from manufacturing practices and hygienic considerations to the selection of materials and the rapidly expanding development of synthetic substances.

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