Bell Laboratories Record

CUMULATIVE INDEX

Volumes VIII to XII

List of Issues, Volumes VIII to XII

VOLUME VIII

No.	1	September, 1929	Pages	1- 52
"	2	October, 1929		53- 92
"	3	November, 1929		93-148
"	4	December, 1929		149-200
"	5	January, 1930		201-252
"	6	February, 1930		253-304
"	7	March, 1930		305-348
"	8	April, 1930		349-396
"	9	May, 1930		397-456
"	10	June, 1930		457-508
"	11	July, 1930		509-564
"	12	August, 1930		565-620

VOLUME IX

No.	1	September, 1930	Pages	1- 52
"	2	October, 1930		53-108
"	3	November, 1930		109-160
"	4	December, 1930		161-212
"	5	January, 1931		213-260
"	6	February, 1931		261-308
"	7	March, 1931		309-352
"	8	April, 1931		353-404
"	9	May, 1931		405-460
"	10	June, 1931		461-508
"	11	July, 1931		509-560
"	12	August, 1931		561-608

VOLUME X

No.	1	September, 1931	Pages	1- 32
"	2	October, 1931		33- 64
"	3	November, 1931		65-100
"	4	December, 1931		101-136
"	5	January, 1932		137-180
"	6	February, 1932		181-228
"	7	March, 1932		229-268
"	8	April, 1932		269-304
'	9	May, 1932		305-340
"	10	June, 1932		341-372
"	11	July, 1932		373-404
"	12	August, 1932		405-436

VOLUME XI

No.	1	September, 1932	Pages	1- 28
"	2	October, 1932		29- 60
"	3	November, 1932		61- 92
"	4	December, 1932		93-124
"	5	January, 1933		125-156
"	6	February, 1933		157-188
"	7	March, 1933		189-220

VOLUME XII

Index of Authors, Volume XII

Index of Subjects, Volumes VIII to XII

NOTE: A biography of the author of each article in Volumes VIII to XII is to be found under the heading "Contributors to This Issue" in the back of the issue in which the article appears.

Captions for Frontispieces

1932

MARCH	Measuring thin sheets of material with an optimeter accurate to one hundred-thousandth of an inch.
APRIL	Sequence switches in a panel dial office.
MAY	Welding by the electric-arc method in the new welding laboratory.
JUNE	An electrometric analysis of a salt solution used for the preservation of telephone poles.
JULY	Turning the die for an experimental transmitter diaphragm, in the development shop at West Street.
AUGUST	Sinking a die for the phenol-plastic mounting of an experimental model.
SEPTEMBER	Lathe-type glass-working machine used in the manufacture of modern power vacuum tubes.
OCTOBER	A new broadcast transmitter (12A) which, with an associated amplifier, covers the power range from 100 to 1000 watts.
NOVEMBER	An iron screw inside its galvanized coating, as photographed in the Materials Laboratory by double exposure with an intervening acid treatment. Each small square is 0.0005 inch on a side.
DECEMBER	Apparatus used at Bell Telephone Laboratories for measuring the quantity of various gases in ferrous alloys.

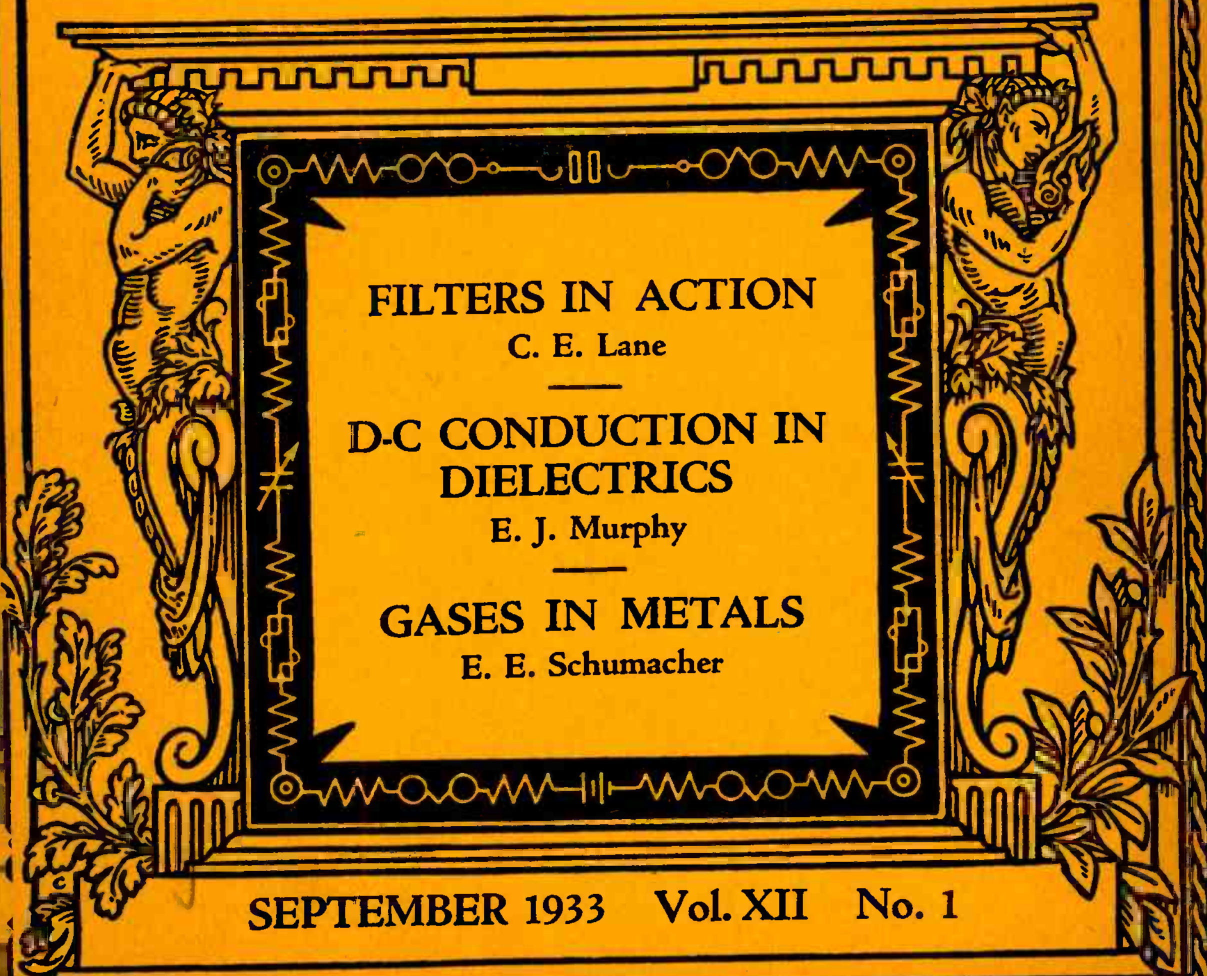
1933

JANUARY	When this central-office fuse blows, the spring makes a contact which rings an alarm, and at the same time raises the colored glass indicating bead so that it can be quickly located and the fuse replaced.
FEBRUARY	Interior of one of the transmitters built in the Laboratories for the new Central America radio-telephone service.
MARCH	X-ray photograph of potted network assembly, taken to show the relative positions of the coils and condensers after the can has been filled with sealing compound.
APRIL	Upper half of jig for testing toroidal cores. The pointed conductors dip into small wells of mercury to form a 75-turn winding around the core to be tested.
MAY	Dr. Leopold Stokowski, Director of the Philadelphia Orchestra, whose voluntary cooperation greatly facilitated the Laboratories' studies leading to the reproduction of music in auditory perspective.
JUNE	Apparatus employed at the Summit laboratories for measuring the rate of flow of humidified gases through wood sections.
JULY	In this unique three-element vacuum tube, on display at the Century of Progress, the plate is coated with a fluorescent material, and the brightness of the luminous bands across it is an indication of the plate current.
AUGUST	Three electrode high-vacuum thermionic tube, developed by H. D. Arnold; used in 1914 as a repeater element in transcontinental telephony.
SEPTEMBER	Measurement of surface leakage on glass insulators.
OCTOBER	The quality of the enamel insulation on wire, once tested by the thumb nail, is now tested accurately by an automatically recording machine.
NOVEMBER	Apparatus for extracting organic materials from various bodies by means of ether.
DECEMBER	In this resistance furnace, crucibles rise through the interior of the alundum tube shown in the foreground while their contents are being heated.

1934

JANUARY	Apparatus used in research studies of photoelectric cells.
FEBRUARY	A group of duralumin transmitter diaphragms studied in the Chemical Department to determine the effects of various metallurgical treatments in corrosion resistance.
MARCH	Loud speakers for reproduction in auditory perspective. In the foreground are the loud speaker and horn for high frequencies.
APRIL	Winding grids for experimental vacuum tubes at the Tube Shop.
MAY	Assembling the 700A Selector used for remote control of radio transmitters.
JUNE	The cathetometer is a convenient means for measuring the deflection of a quartz-spring balance.
JULY	High-frequency quartz plate showing an interference pattern in an optical test for flatness.
AUGUST	The amount of gas evolved from a metal is measured by noting the increase in weight of an absorbing agent suspended on a quartz spring.

BELL LABORATORIES RECORD



FILTERS IN ACTION
C. E. Lane

D-C CONDUCTION IN DIELECTRICS
E. J. Murphy

GASES IN METALS
E. E. Schumacher

SEPTEMBER 1933 Vol. XII No. 1

BELL LABORATORIES RECORD

BELL TELEPHONE LABORATORIES, INCORPORATED
463 West Street, New York, N. Y.

In this Issue

BELL LABORATORIES RECORD

VOLUME TWELVE—NUMBER ONE

for

SEPTEMBER

1933

Filters in Action

By C. E. LANE

Telephone Apparatus Development

MODERN long distance communication, both radio and wire, is dependent in a large measure on the electric filter. Invented by G. A. Campbell of the American Telephone and Telegraph Company, the electric filter consists of a group of condensers and coils so connected that they have the property of readily passing alternating currents of certain frequencies, and of greatly attenuating currents of other frequencies. Those most commonly employed may be divided into three types: the low pass filter, which passes all frequencies below a stated frequency and attenuates all those above it; the high pass filter, which passes all frequencies above a specified value and attenuates those below; and the band pass filter, which passes all frequencies between values known as the upper and lower cut-off frequencies, and attenuates all those beyond these values.

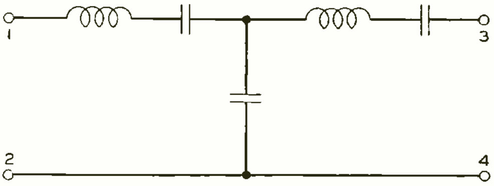


Fig. 1—One form of section for an electrical band pass filter

The unit of filter design is the filter section, of which many different types are possible. A section commonly employed for a band pass filter is shown in Figure 1. A complete filter will include one or more of such identical sections connected in tandem, and the attenuation for any frequency is the summation of the attenuation of all the sections.

A single section, and thus a complete filter to a greater extent, acts in two ways towards alternating currents passing through it. It produces an attenuation and a phase shift—both of which vary with frequency. An ideal phase shift characteristic is shown by the solid line in Figure 2, and an ideal attenuation characteristic is similarly shown in Figure 3. The shape of these curves is the same for a section as for a complete filter, but the actual ordinate values are greater for the complete filter in proportion to the number of sections. It will be noticed that for both phase shift and attenuation there is a sharp break in the characteristics at two points marked f_1 and f_2, and these are the cut-off frequencies.

Ideal filter action requires that the terminating impedance be of a definite value, and this value is different, in general, for each frequency. It is not practicable, of course, to provide a terminating impedance that will have the different values required at each frequency. However, by proper filter design the ideal impedance required for terminating the filter may be made nearly a constant resistance over a large part of the passed band. When this is done, the use of a fixed resistance is quite satisfactory. The effect of terminating the filter in such

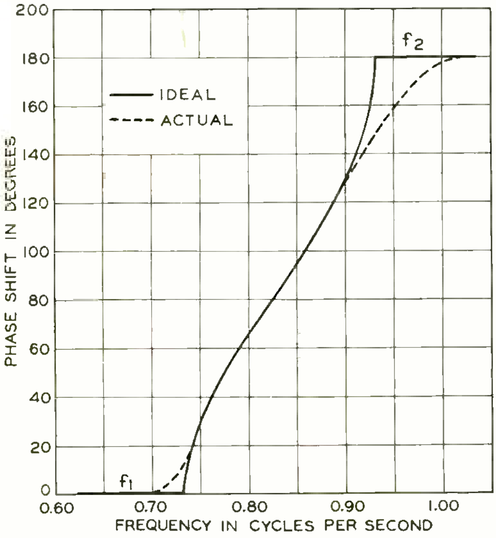


Fig. 2—Ideal and actual phase shift characteristics of a section of a mechanical band pass filter. The electrical analogue of a section of this filter is given in Figure 1

a fixed resistance is to slightly round off the ideal characteristic at the cut-off frequencies, thus giving a characteristic indicated by the dotted lines on the two graphs.

Although the characteristics of filters may be completely and concisely expressed in mathematical terms, it would be very helpful if one could actually see the increasing phase shift and attenuation from section to section. In theory a fairly good indirect method of seeing would be to insert meters in a filter as shown in Figure 4. The variation in excursion of the meter pointers along the length of the filter would indicate the attenuation, and the difference in relative position of the various pointers at any one instant would indicate the phase shift. There is one very obvious difficulty with such a method of watching the action of a filter. If the frequencies were in the voice range or higher, the pointers would move so rapidly that the eye could not follow them. To be able to use this method to advantage the frequencies should be of the order of one cycle per second, but electrical filters for such low frequencies are not practicable.

It is practicable, however, to make a filter for such low frequencies by substituting mechanical for electrical elements. Fundamentally, filter action is a resonance phenomenon, and resonance can be secured mechanically as well as electrically. The action of the pendulum of a clock is a familiar example. A series of pendulums properly connected together may be made to act as a filter, and such an arrangement is shown in the accompanying illustrations. The filter consists of seven sections of the type shown in Figure 1.

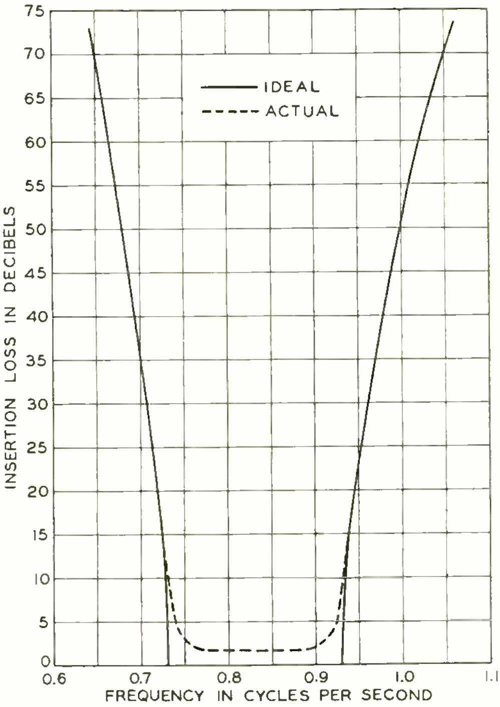


Fig. 3—Ideal and actual attenuation characteristics for seven sections of the mechanical band pass filter

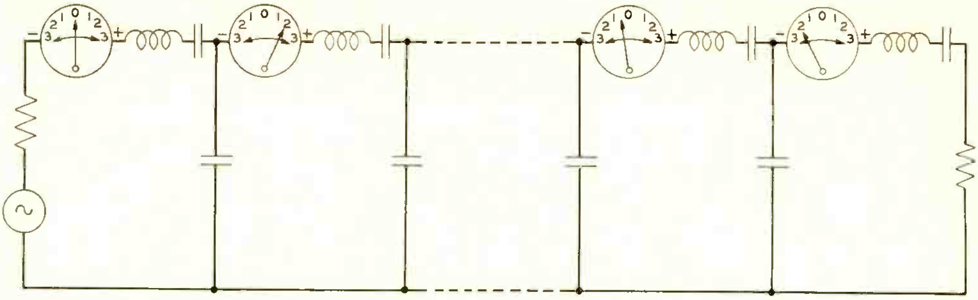


Fig. 4—A band pass filter with meters inserted to indicate the internal operation

In this mechanical filter the mass of the pendulum bobs acts as the series inductance, and the attraction of gravity on the bob, as the series capacitance, while the spring connecting adjacent pendulums serves as the shunt capacitance. The first pendulum at the left is driven from the flywheel of a small motor through a flat spring, and by varying the speed of the motor, the frequency of the mechanical force is changed. A resistance termination is obtained at each end of the filter by allowing the two bobs at the ends of the filter to swing through viscous oil.

The amount of swing of the pendulums corresponds to the current flowing in the electrical filter, and the attenuation produced by the filter can be observed by noticing the difference in amplitude of swing between the first and last pendulums. Phase shift per section is indicated by the difference in position of adjacent pendulums at the same instant. Since at all frequencies up to the lower cut-off there is little or no phase shift, all pendulums will be in about the same relative positions at the same instant for frequencies below the lower cut-off. Above the upper cut-off, the

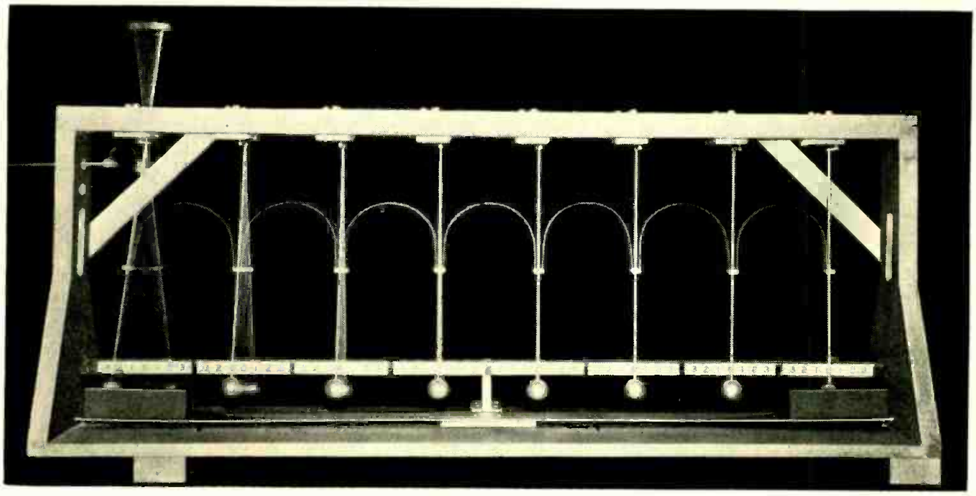


Fig. 5—Operation of the mechanical filter below lower cut-off

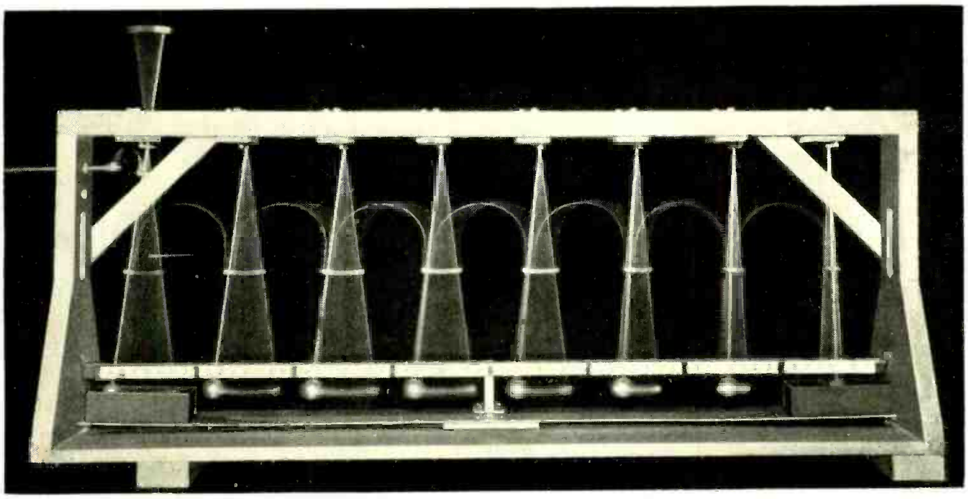


Fig. 6—Just above the lower cut-off the phase shift per section is about 14° and there is a slight overall attenuation

phase shift approaches 180° per section so that when one pendulum is at one end of its swing, the next will be at the other end. Between lower and upper cut-off the phase shift between adjacent pendulums will vary depending on the frequency.

To show these two effects photographically, an exposure of several seconds was made which brings out the total arc of swing of each pendulum. At some instant during this exposure, an instantaneous flash was made which records the position of all the pendulums at the same instant, and thus shows phase shift. The pass

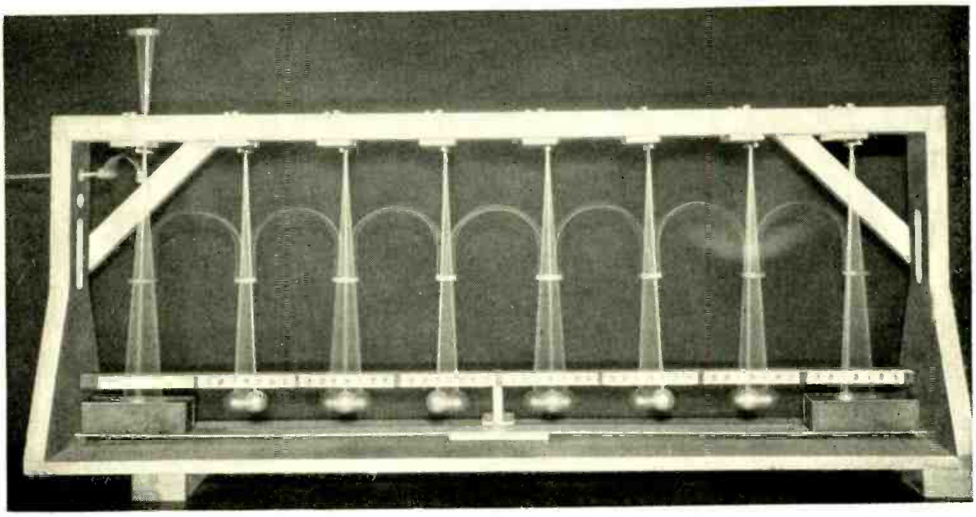


Fig. 7—In the middle of the pass band there is no attenuation, and the phase shift per section is about 90°

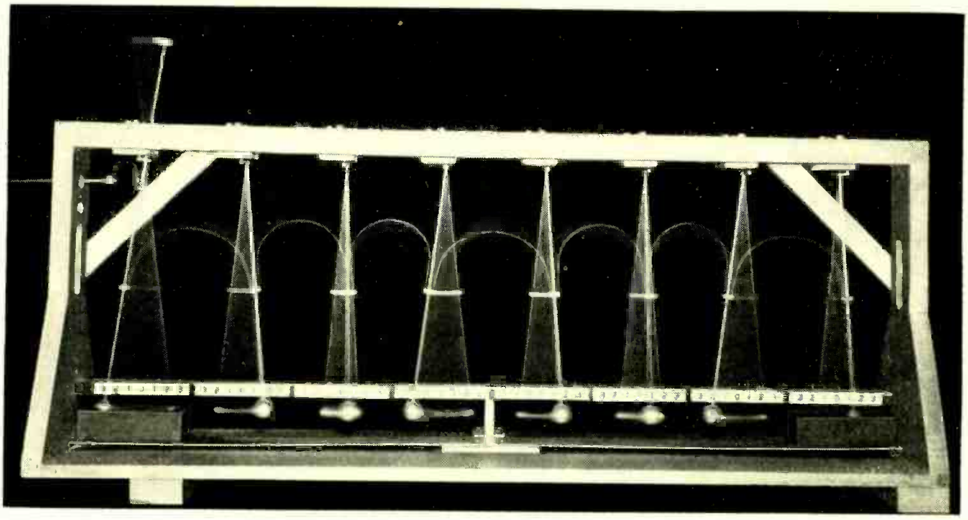


Fig. 8—Just below the upper cut-off a slight overall attenuation is again noticeable and the phase shift per section has increased to 120°

band of this mechanical filter is from 0.73 to 0.93 cycle per second and the accompanying photographs show the conditions at and somewhat below the lower cut-off, at and somewhat above the upper cut-off, and in the middle of the pass band.

In Figure 5 the frequency was 0.68 cycle per second and the large degree of attenuation, about 50 db, is readily evident. Since there are seven sections this means an attenuation of about 7 db per section, and it will be noticed that the second bob has slightly less than half the amplitude of the first; the third, half the ampli-

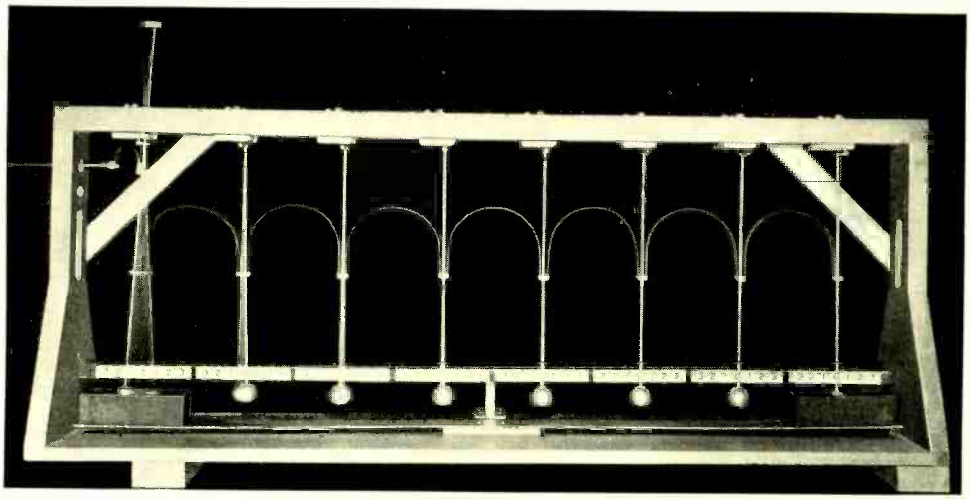


Fig. 9—Above the upper cut-off the large attenuation is evident and the phase shift per section is 180°

tude of the second; and so on. The motion of the fifth bob is so slight that it is barely perceptible. The phase shift, it will be noticed is 0° per section: all pendulums are in exactly the same relative positions.

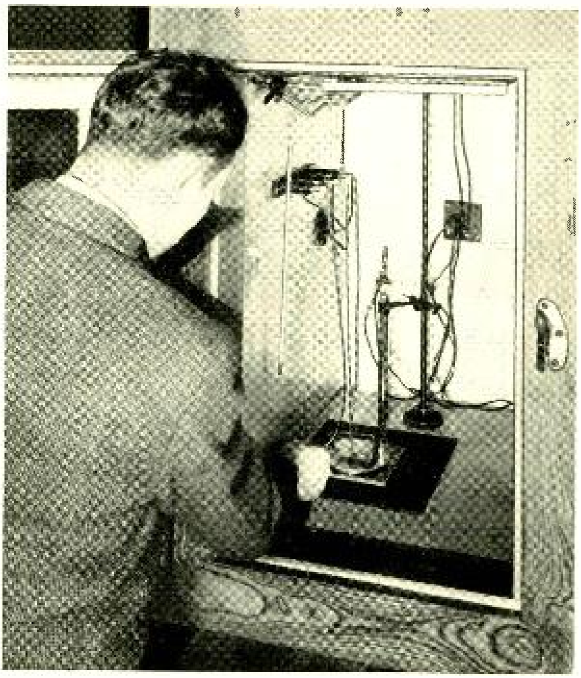
In Figure 6 the frequency is about 0.74 cycle per second, just above the lower cut-off. At this frequency the attenuation per section is very slight but is plainly evident for the overall filter. The phase shift is also small—being 14° per section. The total phase shift for the entire filter is about 98°, and it will be noticed that the last bob is a little over 90° out of phase with the first.

Figure 7, at a frequency of 0.84 cycle per second, shows the conditions at about the middle of the pass band. There is no noticeable attenuation: the amplitude of swing of the last bob is almost exactly the same as that of the first. The phase shift per section is about 90°. In all cases, each pendulum is about 90° out of phase with those on each side of it.

In Figure 8 the frequency is 0.90 cycle per second, just below the upper cut-off. Here again, since the frequency is nearly at the cut-off value, some overall attenuation is noticeable but it amounts to only about 5 db. The phase shift per section, however, is in the neighborhood of 120° which can be seen by noticing that every third pendulum is in the same relative position.

Figure 9 shows the conditions for a frequency above the upper cut-off—at a value of about 1.00 cycle per second. Overall attenuation is 50 db, which is so great that no motion is noticeable at the last bob. The phase shift is the full 180° per section, which is plainly evident in the photograph.

With such a mechanical filter all the phenomena that occur in an electrical filter may be reproduced and actually watched. In the photographs shown only the two characteristics of normal phase shift and attenuation have been illustrated but other effects such as reflections of various sorts, the consequence of using incorrect terminating resistances, and a variety of transient phenomena may be reproduced and visually studied.



Direct Current Conduction in Dielectrics

By E. J. MURPHY
Chemical Laboratories

WHEN a constant potential is applied to a sheet of rubber, a galvanometer of sufficient sensitivity, inserted in the leads, will register a current. This current is not constant, however, as it would be through a metal: it decreases with time, at a rate which varies with different samples of the material. What, then, is one to call "the conductivity" of rubber? This question is frequently answered for practical purposes by taking the current flowing one minute after the application of the measuring voltage as the basis for comparing the insulating quality of commercial samples.

Following this practice, some experimenters once encountered a sample of rubber through which flowed a current unusually large at the outset, and decreasing so rapidly with time that they could not estimate the galvanometer deflection accurately after the minute had elapsed. Thinking some accident caused the anomaly, they removed the potential and then repeated the measurement. This time the current was changing slowly enough to permit accurate measurement, and they accepted this value. Had they repeated the measurement at once, they would have felt confirmed. But had they repeated it next day, they would again have found a large, rapidly changing, initial current.

If these experimenters had attempted to measure, according to the same definition, the conductivity of cotton exposed to high humidity, they would have encountered a phenomenon less bewildering, perhaps, but more deceptive. Their galvanometer would have shown the current to be virtually constant with time. If suspicion prevented them from asserting at once that cotton has a "constant conductivity", and led them to measure the current with a microammeter, more quickly responsive than a galvanometer, they would find that the initial current was some fifty times greater than the value previously observed, and dropped to that value within a second or two.

These examples illustrate a few of the many contrasts between "dielectric" materials and metals as conductors of electricity. When a constant potential is applied to a metal, a constant current flows; but a constant potential applied to a dielectric usually gives a current which decreases with time, and sometimes one that increases with time. Increasing the voltage to any ordinary value leaves the conductivity of a metal unchanged, but may either increase or decrease the conductivity of a dielectric. Reversing the direction of the potential does not affect the conductivity of a metal, but the apparent conductivity of a dielectric so treated may increase sharply and then decrease slowly, or increase slowly and then decrease, or remain virtually unchanged, depending upon the material.

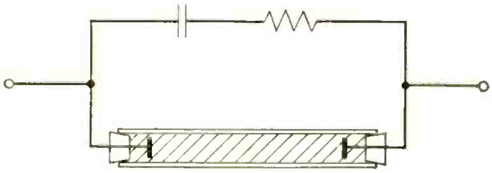


Fig. 1—The simplest model for explaining the behavior of dielectrics as conductors consists of an electrical circuit with two parallel arms, one a condenser and resistance in series, and the other an electrolytic cell

A key to the explanation of the contrasts so far cited can best be provided by citing two more. In the first place, when the potential applied to a metallic conductor is reduced to zero, the current vanishes as rapidly as the inductance of the circuit allows; but when the potential applied to a dielectric is reduced to zero, a current in the opposite direction to the original current will usually be detected by a galvanometer in the metallic circuit connected to the dielectric. This "residual" or "anomalous discharge current" may be quite large even after several minutes. The time required for it to decrease to any given small value, such as the smallest current detectable by the galvanometer used, is greater the longer the time of charging; it may extend into hours or days.

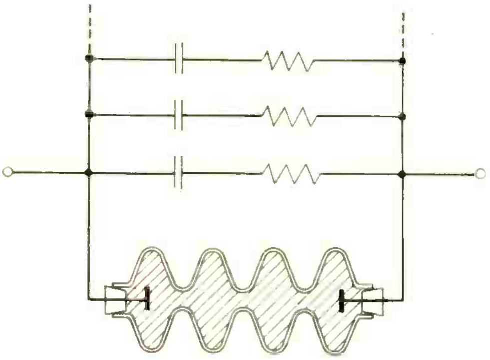


Fig. 2—To accord more closely with the behavior of any particular dielectric, the model of Figure 1 must be complicated by dividing the condenser-resistance arm into several such arms, with time-constants varying from a small fraction of a second to several hours, and the electrolytic cell must be given a complicated shape so that diffusion through it will be slow

Secondly, no matter how long a current of moderate value flows through a metal, the conductivity will vary only with the temperature; but prolonged passage of current through a dielectric often changes considerably its apparent conductivity. Accompanying these changes, and largely explaining them, are chemical changes at the boundaries between the dielectric and the electrodes. These chemical changes occur because in most dielectrics, as in solutions, ions are the current carriers, rather than electrons as in metals. In a circuit through which the current is carried successively by ionic and electronic conduction, chemical changes take place at the boundaries where the type of conduction changes.

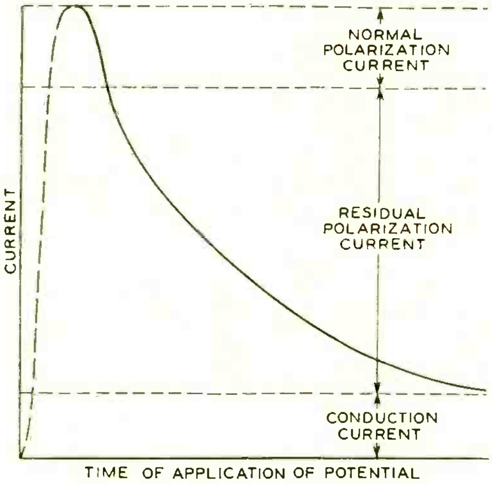


Fig. 3—This curve has a shape typifying the conducting behavior of dielectrics in which residual polarization currents are large relative to the conduction current. The times at which different effects take place differ widely from case to case. The initial current is limited by inductance, or the inertia of the charges

The changes of current with time, observable in many types of insulating materials subjected to a constant potential, are so varied that a model which will predict the properties observed, at least in a general way, is useful. As in Figure 1, a dielectric can be visualized as a condenser and resistance, to account for discharge currents, in parallel with an electrolytic cell, to account for chemical changes electrically produced. The strange behavior of the sheet of rubber focusses attention on the condenser, which was uncharged at the beginning of the first measurement, was partly charged by the current flowing during that measurement and consequently exerted a back e.m.f. at the time of the second measurement, and would have become discharged by the following day. In the case of cotton at high humidity, the electrolytic cell plays the dominant role: the formation, at the electrodes, of electrolytic products weakly dissociated and consequently of high resistance is an important cause of the rapid decrease in the current passing through the material.

This model is in close accord with present theories of dielectrics. Both dielectrics and conductors are considered to be composed of aggregates of positive and negative charges, and differ in that conductors contain more numerous or more mobile free charges, in the form of ions or electrons, than do dielectrics. Whether bound or free, each charge moves so that the resultant force upon it is zero, and thus when a uniform potential is applied the free charges drift in the direction of the electric field, while the bound charges, after moving only a short distance, are restrained by binding forces equal and opposite to those of the field. The current due to the motion of the free charges is called the conduction current; and of the bound charges, the polarization current. The polarization current is the vector sum of the velocities of all the bound charges. In dielectrics this polarization current greatly predominates over the conduction current.

To explain the slow charging and discharging processes observed with many dielectrics, it is only necessary to extend the usual notions of the times required for the formation of a polarized condition in a dielectric. For the formation of one class of polarizations, times of less than 10^{-10} seconds are required. Other polarizations, due for example to molecules with permanent electric moments*, having relaxation times** as long as one-tenth second have been found. There is no reason to suppose it impossible that the relaxation time of a polarized condition might be as great as an hour or more, such as would be necessary to explain the residual-charge effects of dielectrics.

Turning to the electrolytic aspect of conduction in dielectrics, one must notice that diffusion is slower in a dielectric than in the usual electrolytic cell because the dielectric is a solid often of complicated physical structure. Products of chemical changes which take place at the interface between the electrode and the dielectric will only gradually spread by diffusion into the bulk of the dielectric. Thus there may occur electromotive-force effects such as are produced in concentration cells, and the resistance may change according to the nature, rapidity of formation, and distribution, of the products of electrolysis.

The simple electrical model can readily be adapted to these complexities (Figure 2). The condenser-resistance arm can be divided into several parallel arms, one for each type of polarization involved, and each with a time constant corresponding to the relaxation time of the polarization it represents. The electrolytic cell can be given the same conductance as that contributed by the free charges in the dielectric, and can be built with such a tortuous conformation that changes in resistance, and in concentration-cell effects, could persist for many days. This model may be regarded as translating some general features of the present theories of dielectric behaviour into terms involving simpler systems (capacities, resistances and electrolytic cells) whose properties are very familiar. Its usefulness lies in providing a means of interpreting the complicated changes of current with time and of selecting the proper value of the current on which to base a measurement of conductivity.

Anyone inspecting this model would immediately say that its direct-current conductance, properly speaking, was the conductance of the electro-

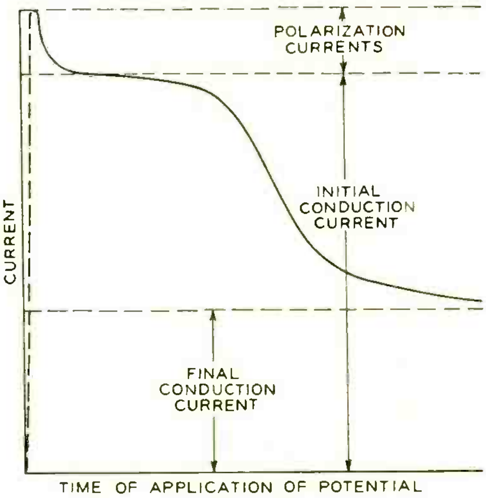


Fig. 4—The shape of this curve typifies the conducting behavior of dielectrics in which the residual polarization current is negligible in comparison with the conduction current, and electrochemical reactions modify the conductance appreciably

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*Record, 1931, June, p. 462; July, p. 535

**The relaxation time is the time required for polarization to fall to $\frac{1}{e}$ th of its original value, where e is the base of Naperian Logarithms lytic cell before electrochemical reactions had changed its composition appreciably. It is the corresponding property of a dielectric which can best be called its "true conductivity"*, because it is this property which measures the number of free charges times their mobility, and thus corresponds to the similarly-named property of a metal. It is difficult to measure this property in some cases, for it is hard to separate the true conduction current from polarization currents, and to be sure that the passage of current has not changed the composition and the resistance of the dielectric. Figure 3 shows that for dielectrics of low d.c. conductivity, the value of the current which prevails after it has stopped changing rapidly with time is the proper value on which to base the calculation of the true conductivity. Figure 4 applies to dielectrics of high d.c. conductivity, which exhibit a current decreasing with time because of electrochemically produced changes in the composition of the material. Here it is evident that the true conductivity should be calculated from the value of current prevailing soon after applying the potential. The value in question corresponds to the comparatively flat portion of the curve after polarization currents have become negligible and before the cumulative effect of electrolysis produces an appreciable change in the composition of the material and a resulting change in the conduction current.

Obviously a knowledge of the "true conductivity" of a dielectric may sometimes be of less practical importance than a knowledge of some apparent conductivity. In the case of cotton at high humidity, where the polarization current is relatively small, the initial high conductivity, missed altogether by the galvanometer, is probably close to the "true conductivity", but it is for some purposes less useful to know this value than to know the value of the lower and more stable conductivity almost immediately reached. In measuring the conductivity of rubber sheet, where the one-minute value of conductivity includes an appreciable contribution due to polarization currents, the experimenters came closer to the "true conductivity" in their second measurement. Had they accepted their first measurement, however, even though inaccurately estimated on the galvanometer, the value would have been a better means of comparing this sample with others measured according to the definition of conductivity which they used.

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*The "true conductivity" may be defined as the conductance per unit cube contributed by the free ions.

Water at West Street

By A. F. LEYDEN
Plant Department

FORTY million gallons of water, the amount which passed into the West Street buildings during 1932, is comparable to the amount of water annually supplied to a small suburban community. Its provision is a task of equivalent scope and importance, and the growth of the Laboratories, as of a community, has necessitated continuous development of the water system. A failure of the system at any time would leave the Laboratories thirst-parched, unclean, and at the mercy of fire.

In contrast with the ordinary community, which must often build its own reservoir, the Laboratories draws its water, through twelve metered connections, from the city mains which pass it on all four sides. On the other hand it must distribute its water over a fairly large vertical range, and pressure problems are thus encountered which are not present to

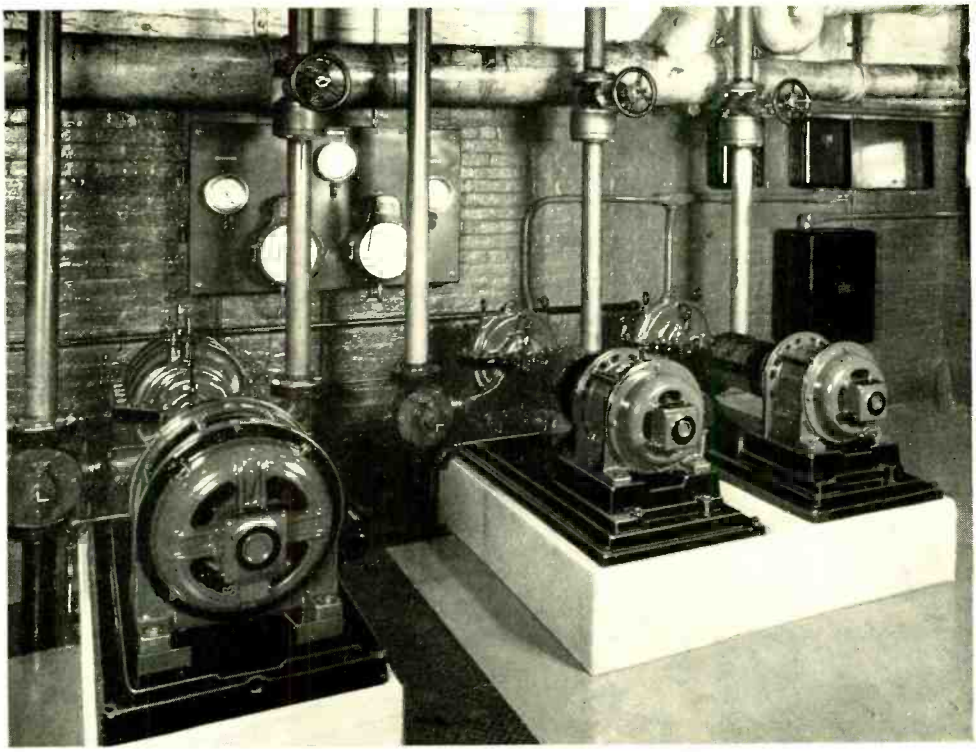

Fig. 1—The pumping station in Basement B

complicate the horizontal distribution of water in most small suburbs.

Water for general purposes is distributed through the Laboratories in part directly from the mains and in part from tanks on the roof. The city water pressure is adequate for distribution in buildings not more than five stories high, and accordingly the water from the mains supplies directly Sections G, I and L, the first five floors of Sections J and K and certain special areas in the lower floors of Sections C and H. To the remaining areas of the Laboratories, Sections A, B, C, D and H, and the upper floors of Sections J and K, water flows from tanks elevated in a penthouse above the roof of Section 13-D, and filled by pumps. The drinking water system*, which is separate from the general system, draws its water independently from the mains. Two connections with the mains are employed solely for the emergency fire pump in Basement H.

Thirty per cent of the water flowing into the Laboratories is used for cooling purposes, as in the high voltage vacuum tubes in Section 2-G, the air conditioning machine in Section L, and the ammonia compressors in Basement B. Since this water passes through the cooling jackets in a closed piping system, it is in no way impaired, although its temperature is raised sometimes as much as 20 degrees F. This water is therefore returned to suction tanks in the basement, and thence pumped to the roof tanks for further use, in the sanitary and fire-prevention systems, along with water taken directly from the mains.

For more than a quarter century the pumps supplying the roof tanks were driven by steam generated in our boiler plant. In 1924 the Plant Department proved it economical to give up our isolated electric generating plant in favor of public utility electric power. Two electrically driven centrifugal pumps took over the pumping task, and the steam-driven pumps were shut down, remaining as emergency

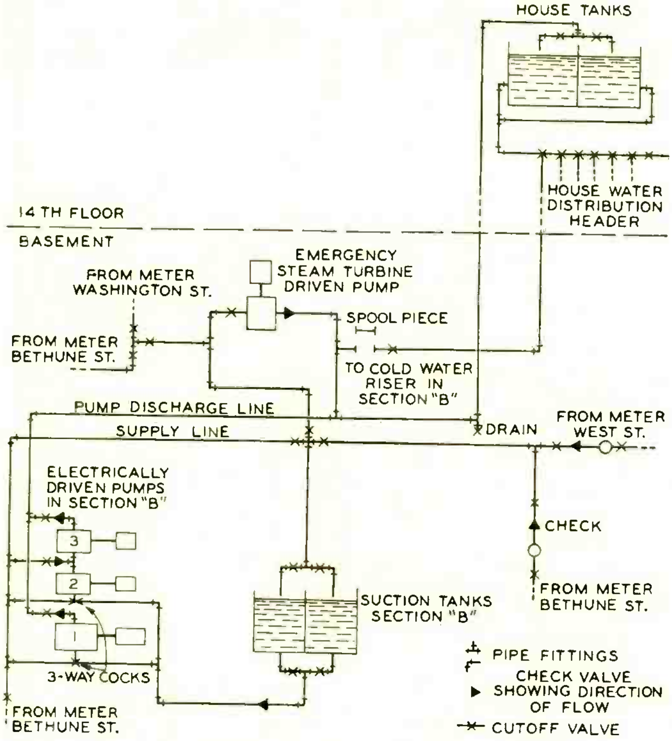

Fig. 2—Schematic of the piping of the general house water system

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*Record, July 1927, p. 403

equipment in the event of outside power failure. The following year, to conform with newly enacted legal requirements regarding elevation and reserve capacity for fire stand-pipe use, new and larger house tanks were built at a higher elevation and the original tanks were removed from the 13th story roof level. This greater elevation placed an added burden on the electric pumps, but larger impellers overcame the handicap.

In 1926, after two years of reliable service, the new electric supply received the stamp of approval, and the steam-driven equipment was removed. The need for an emergency standby for the electric pumps still existed, however, and the Plant Management selected a steam driven centrifugal pump capable of operating at the much reduced steam pressure set at the time the isolated electric plant shut down. The characteristics of this turbine make it economical to run the pump regularly during the winter, since the exhaust steam can be used for the heating sytem.

Fig. 3—One of the more spectacular uses of water in these Laboratories' research is in the accelerated corrosion tests on the roof of Section G

The demand for water gradually outgrew the electric pump capacity, and the peak demands of the summer of 1930 made it necessary to run the turbine-driven pump to assist the electrics. As a routine operation, this method was not justifiable, for the turbine was non-automatic and unsuited to regular summer operation when available steam is at a minimum. The choice of additional equipment logically went to a larger electrically driven pump. Accordingly, the present pumping station in Basement B, which already housed the suction tanks, was engineered and installed by the Plant Department.

This installation is shown in Figure 1. The pump at the left is the latest acquisition, a Goulds three-stage pump rated 200 gallons per minute at 225 foot head. The other two are the original pumps installed in Basement D in 1924, each delivering 125 gallons per minute at 130 foot head. These three electric pumps can draw from the City mains or from the suction tank. The turbine driven pump (not

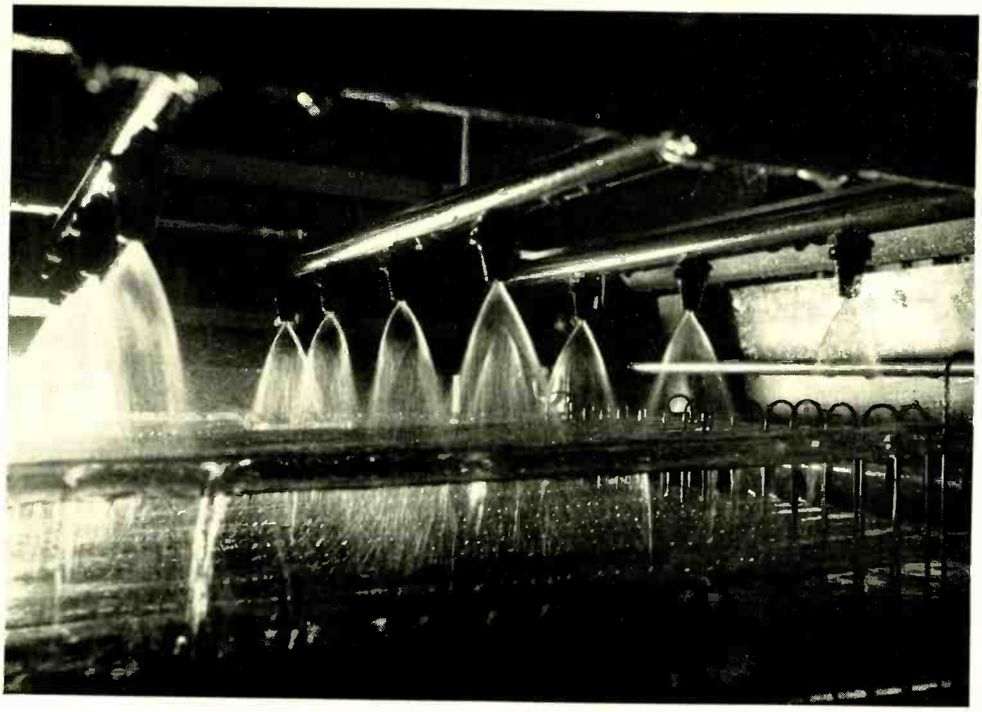
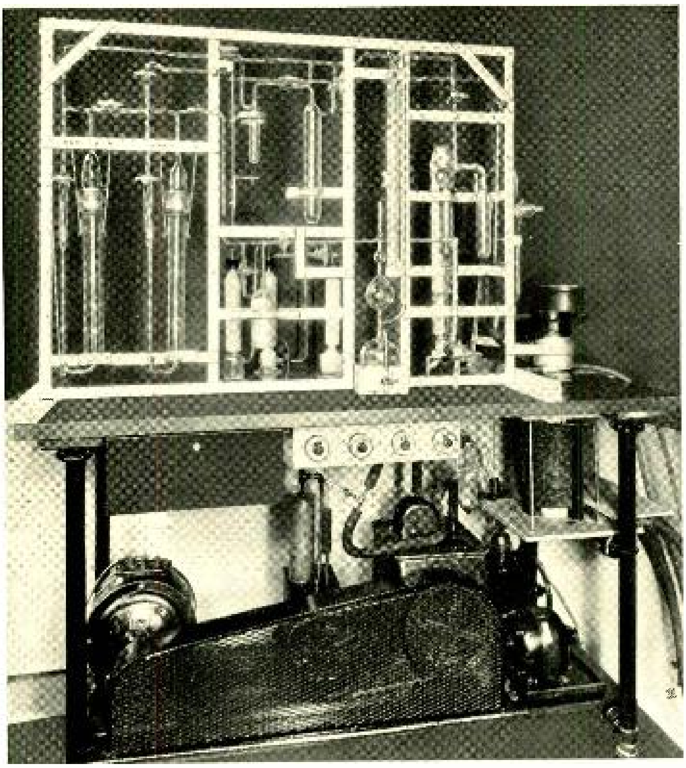


Fig. 4—Experimental sound-picture film is washed by water sprays in Section L

shown in Figure 1), which delivers 250 gallons per minute at 130 foot head, draws from the mains only. Their method of coordination is shown in Figure 2.

Normally the two older electric pumps operate in series from the suction tank, delivering 175 gallons a minute to the roof. Should the suction tank become empty, the center pump stops, leaving the pump at the right drawing from the City main to supply approximately the same amount. Proper location of check valves, and the use of float switches on all tanks, make this operation entirely automatic.

The higher rating of the new pump enables it to draw from the suction tank, pumping directly to the roof approximately 200 gallons per minute. The delivery characteristics curve on which the pump was selected is such that, drawing from the City mains at considerably higher suction pressure, it will still operate satisfactorily in parallel with the other two electric pumps. A proper manipulation of valves permits the operation of all three pumps in a series-parallel combination, capable of delivering more water than can conceivably be demanded for a long time ahead. This arrangement provides as flexible a system as any building operator could desire.



Gases in Metals

By **EARLE E. SCHUMACHER**
Chemical Laboratories

THE presence of minute traces of gas in a metal may change its properties radically. The magnetic permeability of commercially pure iron, for example, may be greatly increased by eliminating the small amounts of gas that it contains. A few thousandths of one per cent of oxygen in copper will make it useless for certain purposes. Since iron and copper and, in fact, most metals are used extensively in the telephone industry, the effect of gases on them is of extreme importance to the Bell System. In the metallurgical laboratories, sensitive equipment is available for measuring the gas content of metals and for obtaining metals in an essentially gas free condition.

Although it is not difficult to obtain metals that are moderately free from gases, a prolonged treatment under high vacuum is required to obtain the high degree of purity required for research studies. To drive off the gas, the metal is heated in vacuum above the melting point, but the process is often complicated by the fact that, even at low pressures, sufficient gas may remain in the metal to be troublesome. If this occurs, a process consisting of alternately melting and partially solidifying the metal under high vacuum may be employed to take advantage of the decrease in gas solubility at the freezing point. Almost complete elimination of gas may be obtained in this manner.

The apparatus employed in the metallurgical laboratory is shown diagrammatically in Figure 1. Essentially, it provides both a means of melting the metal in a closed chamber and facilities for maintaining a high vacuum in the chamber during the entire operation. Since the effectiveness of the method depends largely on the degree of vacuum that can be obtained, the improvements incorporated in the present apparatus are for the most part associated with securing, maintaining, and measuring extremely low gas pressures.

The metal to be freed from gas is placed in a shallow boat of fused aluminum oxide—known by the trade name of alundum. This form of container rather than the more usual deep crucible was adopted in order to secure a greater surface exposure, as well as to reduce the head of metal through which the gas must pass to escape. The boat is placed within a cylindrical alundum heat radiation shield which rests on two alundum cradles. This whole assembly is then sealed in a pyrex glass tube, which connects to the pumping system.

After the apparatus has been sealed, and the pump has been placed in operation the gases adsorbed on the glass walls and assembly are driven off by baking in a nichrome resistance furnace which is placed around the furnace tube. The temperature of 450° C. is maintained until gas is no longer liberated from the apparatus. A high frequency coil is then substituted for the nichrome furnace and the metal in the alundum boat is melted by induced high frequency current. Since the alundum shield shuts off considerable radiated heat,

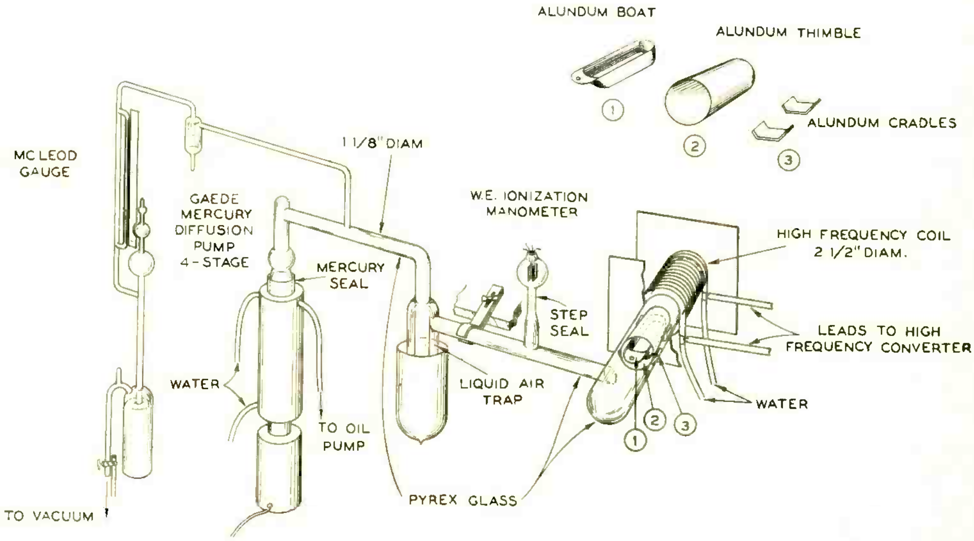


Fig. 1—*Apparatus developed in the metallurgical laboratory for freeing metals of gases*

and the high vacuum prevents heat transfer by conduction and convection, it is possible to keep the metal at its melting temperature indefinitely without heating the pyrex glass tube to its softening point.

The gases given up by the metal are pumped out of the system by a 4-stage Gaede mercury diffusion pump backed by an oil pump. A liquid air trap prevents mercury vapor from passing back into the furnace tube and, in addition, increases the efficiency of the pumping system by removing the carbon dioxide and water vapor. Rough measurements of the gas pressure, particularly during the period of lower vacuum at the beginning of the process, are measured by a McLeod gauge connected to the system between the vacuum pump and the liquid air trap. Measurements of the very low gas pressures existing during the later stages are made with an ionization manometer connected between the liquid air trap and the furnace. The final pressure may be as low as one billionth of an atmosphere.

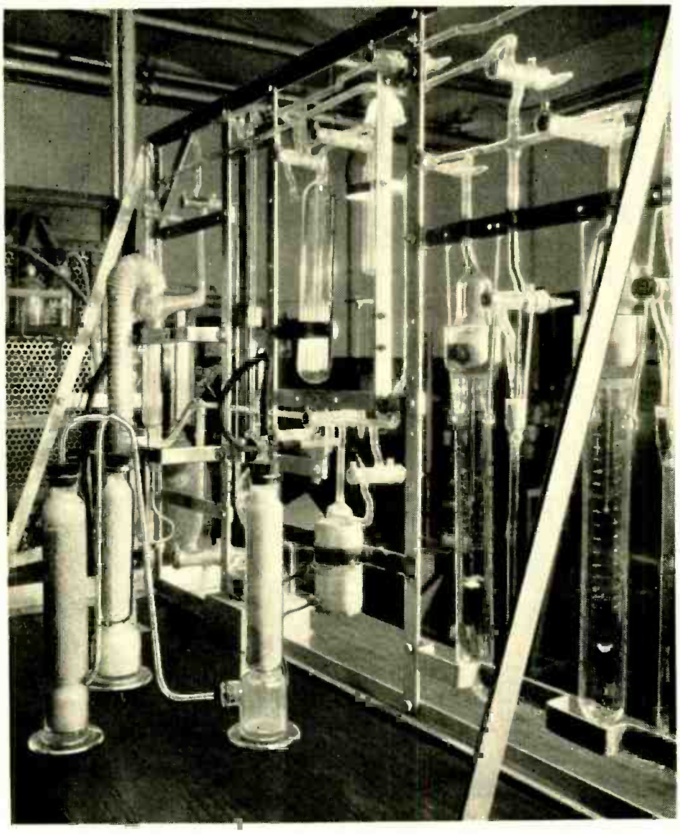


Fig. 2—*At the right are the light glass weighing baskets suspended from quartz springs which contain the absorbents for water and carbon dioxide*

To measure the quantities of gases in iron and its alloys, the apparatus shown in the photograph at the head of this article and in Figure 2 is employed. These gases are chiefly oxygen, hydrogen, and nitrogen. The gas is removed from the metal for analysis by induction heating much as with the gas elimination apparatus just described, except that the crucible material is graphite instead of alundum.

The procedure with this apparatus is first to heat the furnace to a high temperature and at the same time to run the exhaust pump. This frees the furnace structure from adsorbed gases and creates a moderate vacuum. After this preheating operation, the vacuum pump connection is closed and the sample of metal to be analyzed is dropped into the hot crucible from a vacuum compartment located above the furnace. By means of the induction heater, the metal is then

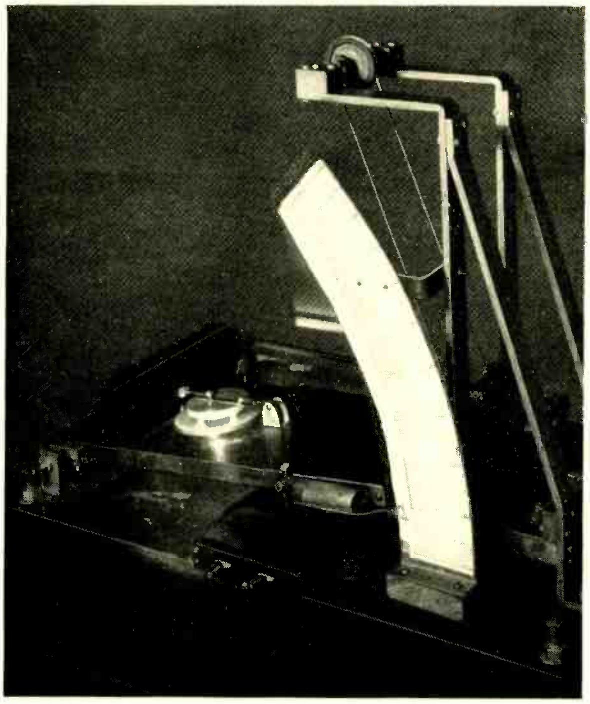


Fig. 2—The brushes are hinged so they may be lifted up for the insertion of the slider

to a six inch radius. It is light enough so that at 72° F and 50% relative humidity — the atmospheric conditions established for the test — no noticeable indentation is made in the surface of the wax when the tripod is carefully placed on it. Possible irregularities in the results, due to variations in the wax surface, are diminished by employing a three legged device rather than a flat or spherical one. It was found that a smooth uniform surface texture could be obtained by heating the wax compound to a liquid state and pouring it while the dish was cold. This procedure must be carried out according to a detailed specification.

In the apparatus employed at the Laboratories a small motor, mounted independently of the test apparatus and connected to it through a rubber tube to eliminate vibration, serves to raise one end of the plane at a uniform and adjustable rate. Speed control is obtained by use of a brake in conjunction with a slide-wire resistance in the armature circuit. The motor is reversible, and the control key is arranged so that the resistance is in the circuit only while the plane is rising, thus allowing the plane to be returned rapidly to the horizontal position.

There is no definite angle at which the slider begins to slip on wax compounds. Even at small inclinations the slider will move downward very slowly. Although time, angle of slope, and distance moved are thus all involved in the measure of tackiness, the angle of slope is the most important factor. As the base is tipped up the tripod moves imperceptibly even at very small angles, but it begins to move appreciably only at some definite and larger angle. To allow for the slow creep at small angles without appreciably affecting the angle at which the major movement begins, a small amount of motion must be allowed before the measurement of angle is made.

To determine when the slider has moved the specified distance, an electrical circuit is employed of which the slider is a part. The movement of the slider and the resulting breaking of this circuit releases a drop which carries a pencil to make a mark on a strip of paper to indicate the angle attained by the plane. The details of the apparatus are shown in Figure 2. A strip of contact metal is fastened to the top of the slider running lengthwise with the base. Two brushes rest lightly on this strip; the one nearest the hinge of the base remains in contact as long as the slider is on the sample, but the upper contact projects inward from the edge of the slider only a definite distance, determined by a small projection from the lower surface of the brush. At the beginning of the test this projection is allowed to rest against the edge of the slider.

This upper brush may be moved in its support so that the slider may be placed in any convenient place on the sample and then the upper contact moved until the projection on the lower side just touches the edge. The motor is then started, and when the slider moves out from under the upper brush, the circuit is broken, and the pencil marks the angle the plane has attained. This mark is made on a piece of paper fastened along the edge of a permanent scale with scotch tape. The scale is graduated in tangents of angles in steps of 1/100 of the tangent of the angle from zero to forty-five degrees.

There are a number of variables which can be only partially controlled, but with reasonably careful manipulation the tackiness test gives reproducible results which are in keeping with the results obtained from the compounds in use. Beeswax compound, which has given good results in service for a number of years, was taken as the standard for an acceptance test for this class of material, and the test definitely eliminates several compounds which are known to be undesirable.

THE USE OF THE TELEPHONE

"*Typical of this nation's ready acceptance of mechanical convenience,*" *says a recent editorial in the* NEW YORK EVENING POST, "*is the universal use of the telephone, set forth in figures which show that 56 per cent of all the world's telephone numbers are listed in the United States. The number of phones per capita, or 'telephone density', of this country is eight times that of Europe. Canada comes second in this respect and Denmark third. The usefulness of the telephone increases according to the number of telephones in use. It would be small advantage to possess one if there were nobody to call by means of it. This is an enviable industry, therefore, which can offer better service as it comes closer to the saturation point. With 15.8 telephones to every 100 persons in the United States, the saturation point is still some distance away.*"

A Current Transformer for Low Radio Frequencies

By L. B. HILTON

Telephone Apparatus Development

THE development of radio frequency circuits operating at high power levels has recently created a demand for apparatus suitable for the measurement of large currents at radio frequencies. In general the most convenient method of measuring large alternating currents is to use a current transformer, in which is induced a relatively small current whose value may be read on a small alternating-current ammeter. Current transformers for power frequencies have long been available and are in common use commercially. They have also been used in a few low-power applications at radio frequencies in the long wave transatlantic telephone link. For high-power use at radio frequencies, however, it was necessary to develop an improved type to measure high currents, with insulation suitable for the accompanying high potentials to ground.

Such a transformer, designed for measurements at radio frequencies of the order of sixty kilocycles, is shown in Figure 1. It can be used to measure currents ranging from 10 to 500 amperes in conductors whose potential above ground may be as high as 10,000 volts. The conductor carrying the current to be measured is placed through the opening in the center of the apparatus, to act as the primary winding of the transformer.

The secondary windings are inside the apparatus proper and are arranged about the permalloy-dust core in such a way as to make possible the precise measurement of a wide range of currents with a single instrument. This is accomplished by designing the transformer secondary windings so as to provide four different current ranges for maximum currents of 500, 300, 100, and 50 amperes in the primary conductor. For each range, the transformer is designed so that the current from the transformer windings reaches a maximum of one ampere when the primary conductor current is the maximum for that current range.

To measure the current a thermo-ammeter with a range of zero to one ampere, is connected to the secondary windings. The thermo-ammeter has two parts which may be widely separated, the thermo-couple or "heating element", and the meter. A special compartment is provided in the top of the transformer to hold the thermocouple, which can thus be connected easily to the transformer windings and yet kept completely shielded from any external high power circuits. By heating this element, a radio-frequency current of one ampere flowing through it causes a DC potential to be impressed on the meter which produces a full scale deflection. The typical calibration shown in Figure 2 for a transformer of this type indicates the wide range of primary conductor currents which it can measure, and illustrates the overlapping of the different current ranges for greater precision of measurement. The instrument draws very little power from the circuit for its operation,—only a small fraction of a watt per ampere.

A current transformer for either power or radio frequencies must have its secondary terminals short-circuited if the meter is disconnected. Failure to do this would cause an excessive rise in voltage at the transformer terminals, which would create a dangerous operating condition and might even destroy the transformer. In the new radio-frequency current transformer, this danger has been eliminated by providing a permanently connected protector* inside the transformer, which will prevent the building up of excessive secondary voltages in the transformer if the heating element should accidentally be left disconnected.

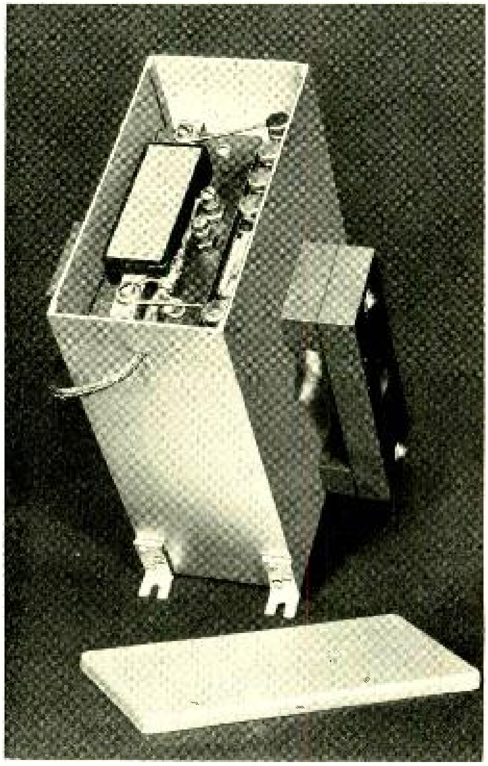


Fig. 1—The conductor carrying the current to be measured is passed through the center of the current transformer and held there by the insulating bridges at both sides. The heating element for the thermo-ammeter, in the upper part of the transformer, is connected to one of the four binding posts (upper right) for the desired current range

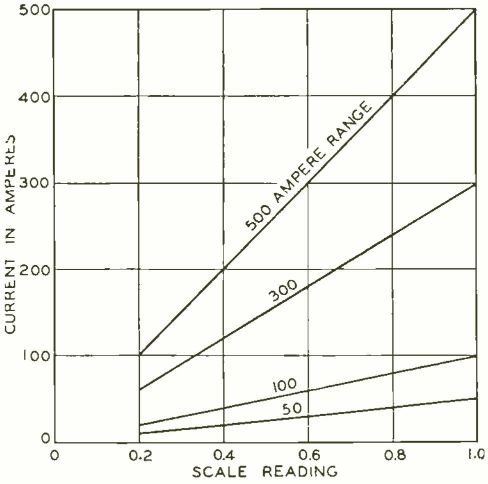


Fig. 2—By providing four current ranges in one current transformer, the instrument is given wide utility

Since the normal circuit potential between the conductor and ground may be as high as several thousand volts, alternating at radio frequencies, the conductor must be carefully insulated from the case to prevent breakdown and to avoid the possibility of corona formation, with consequent loss of energy and introduction of noise into the circuit. The illustration shows how this transformer has been constructed to enable it to operate satisfactorily up to approximately 10,000 volts. Insulating bridges, located well away from the

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*Including the Nos. 26 and 27 protector blocks, described in the RECORD for November, 1932, p. 80.

opening, hold the conductor centered in the opening. No insulating materials other than air are permitted in the space between the conductor and the metal transformer case. For the highest voltages the inside surface of the transformer opening must be smoothed or polished to remove every irregularity and the outer surface of the conductor must also be smooth. Each end of the opening is smoothly flared on a large radius. The size of conductor fitting the bridges is the optimum for the transformer dimensions,—a smaller conductor diameter reduces the potential at which corona forms, and a larger reduces the breakdown potential.

Before a current transformer was developed, large radio-frequency currents were usually measured by means of high-current thermo-ammeters. The meter, and the wires connecting it to the heating element, were at the same radio-frequency potential as the heating element, and all had to be carefully insulated from ground. When the meter was located on the operating panel, glass windows had to be provided to protect the operating personnel from the high voltages.

Current transformers offer decided advantages over the directly connected thermo-ammeters previously used. One of the new transformers, with its single low-current meter, can measure as wide a range of currents as can be measured with several different thermo-ammeters, which are especially expensive in the larger sizes. The transformer may be placed anywhere in the circuit over existing conductors. The high insulation of the transformer permits the transformer case, meter and connecting cable to be grounded, thus simplifying the installation and providing maximum safety to the operator.

A number of these current transformers will be installed at various points in the antenna coupling circuits of the high-power amplifier in the proposed long-wave transatlantic radio transmitter. In these circuits they will operate at frequencies in the neighborhood of sixty kilocycles. While the transformer illustrated is designed primarily for the frequencies used in this transmitter, the design can be modified for much higher frequencies such as are used in high-power radio broadcast transmitters.

Fuses

By E. S. SAVAGE
Telephone Apparatus Development

OF the eight million fuses produced annually in normal times for use in the Bell System, the great majority fall into two general classes, the tubular and the flat. Both of these types operate on the same familiar principle: a fusible conducting element, heated by the current passing through it, melts or vaporizes in some portion when the current reaches the limiting value, and opens the circuit. The current at which the fuse will "blow" is determined largely by the material and dimensions of the fusible element.

Tubular fuses, of which the No. 11 (Figure 1) is a good example, consist essentially of a cylindrical shell of an insulating heat-resistant material with metal plugs in each end serving as terminals between which a fuse wire passes through the tube. The tube is generally made of red fibre, but in some cases of black fibre, porcelain or glass. The fuse wire usually is made of lead or a lead alloy; it is soldered to the metal plugs, and in a number of cases is enveloped by asbestos sleeving. In the case of fibre fuses, a vent hole in the end, or transverse slots in the shell permit the escape of gases generated and expanded by the intense heat developed when the fuse blows because of severe overload.

The principal use for tubular fuses of this type is for the protection of central office and station apparatus from abnormal current due to contact with electric light and power lines.

Fuses of the flat type are used in battery supply circuits for the protection of the apparatus in central offices. In its simplest form, the No. 24 (Figures 2a and 2b), this type of fuse consists of an insulating strip made of phenol fibre with metal terminals at the ends, between which the fuse wire passes. The terminals are notched, one longitudinally and the other transversely, enabling the fuse to be clamped in place by slipping the notches under the heads of machine screws without removing the screws from the fuse posts or mounting bars.

Fuses of the flat type are usually mounted on panels in central offices in large numbers, and under these

Fig. 1—Tubular fuses, such as the No. 11, are used in protectors and cable terminals

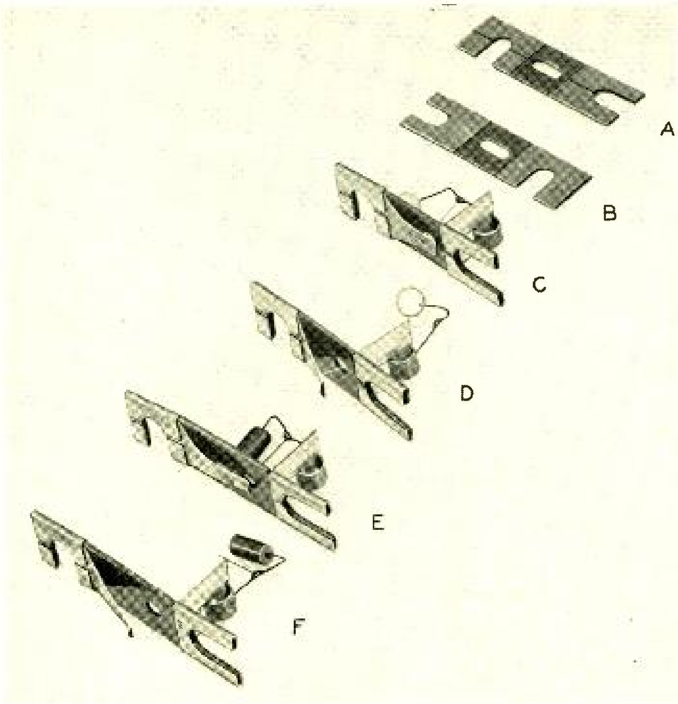


Fig. 2—Central-office fuses have evolved from the simple flat-type fuse, No. 24 (a and b), to the indicating alarm fuses of two sizes: larger, No. 35 (e and f); and smaller, No. 44 (c and d)

conditions it would be difficult to locate a blown No. 24 type fuse. Accordingly, the present standard central office fuse, the No. 35 type (Figures 2e and 2f), embodies an alarm and a simple automatic indicating device. To the terminal having the longitudinal slot is attached a helical spring and to the other terminal a flat spring. The helical spring is on the upper side and the flat spring on the under side of the fuse. The fuse wire is stretched between the free end of the helical spring and the free end of the flat spring through a small hole in the insulating strip. The extreme of the free end of the helical spring carries a short length of colored glass tubing, the "bead." In these "indicating alarm" fuses, the use of differently colored beads distinguishes between the different capacities. When the fuse operates (Figures 2d and 2f) both springs are released, the helical spring raises the bead into a conspicuous position, and the flat spring closes an alarm circuit through the alarm bar on the fuse panel which operates a bell and a signal light.

Fuses of this sort are usually mounted so close to one another that when used in circuits of the order of 130 volts, the operation of a fuse is often attended by enough arcing to cause false operation of adjacent fuses. In fuses so used, the fuse wire is now enclosed in glass tubing (Figure 3) which confines the side flash and thus protects the adjacent fuses.

As insurance against installing a flat fuse of high capacity where a low capacity fuse should be, the lower

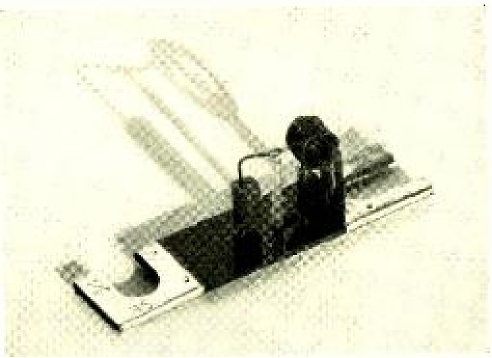
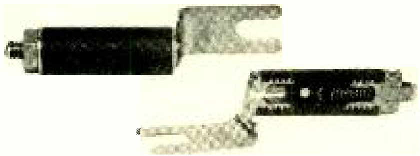


Fig. 3—Glass tubing confines the effects of the arcing which often accompanies the operation of flat-type fuses used in 130-volt circuits

capacities are slotted for No. 10 mounting screws, and the higher for the smaller No. 6 screws. In the unequipped positions on panels for flat type fuses, dummy fuses (No. 63A or 64A) of black insulating material, are inserted so as to prevent the insertion of fuses in these positions through error when replacing operated fuses in adjacent positions.

Still in some use is a non-indicating alarm fuse (No. 43) with an alarm spring the same as that of the indicating fuses, but without the helical spring and glass bead.

Outside of these most widely used types of fuses, there are a few others, manufactured in relatively small quantities to fill special functions. Examples are those, such as the Nos. 60 and 62 types (Figure 4), in which the fusible element is a globule of low melting alloy joining two heating wires which are placed under tension by a small helical spring. Currents above a definite value heat the wires enough to soften the globule, so that the spring pulls the wires apart.



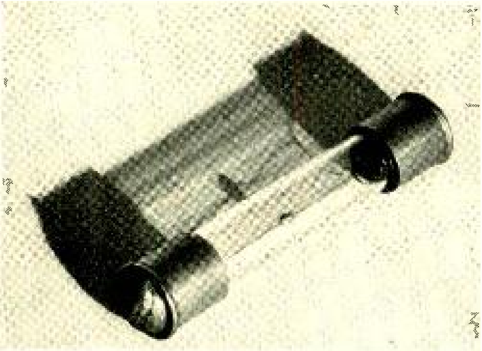


Fig. 4—The No. 60 (above) and 62 (below) fuses are more nearly heat coils than fuses in principle

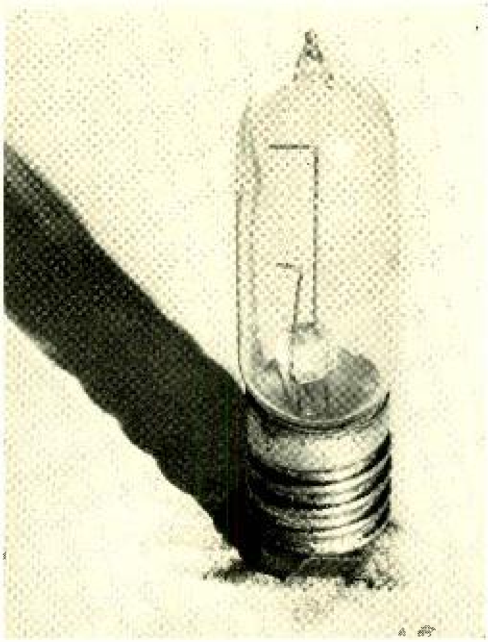


Fig. 5—The No. 59A fuse is sensitive to extremely small currents

To protect delicate apparatus such as thermocouples, an unusual fuse, the No. 59A (Figure 5), has been developed which will blow at a very low value of current. It consists of a small fusible resistance wire about four ten-thousandths inch in diameter, mounted inside an evacuated glass bulb. So mounted, the wire will melt when carrying a current of not more than one-fortieth of an ampere, one-third of the value at which it will blow if in air. Besides increasing the sensitivity to this extent, the evacuated bulb protects the fine wire from atmospheric corrosion and mechanical injury.

Interesting problems arose in developing a method of manufacturing the fine resistance wire to exacting specifications. It was found that drawing the wire through a diamond die to the proper dimensions was extremely difficult when the diameters of the wire and die were so small. A process was accordingly devised in which a wire larger than desired is electrolytically etched to the size required. By determining the resistance of the wire as it passes through the etching solution, its final dimensions can be held within very close limits.

In the design of apparatus like fuses, used in such large quantities by the Bell System, close attention to details of construction, cost of materials and manufacture is necessary. Further to hold the System's fuse bill to a minimum, systematic repair of blown fuses is carried on in the shops of the Western Electric Company.

POPULARIZING SCIENCE

In reporting the addresses of leading scientists who joined with Science Service in its recent conference on the diffusion of scientific knowledge, the Science News Letter for July 22 said in part: "Dr. Robert Andrews Millikan . . . . . held that scientists themselves should be trained to express themselves in condensed and popular language, not only for the education of the public but for their own benefit in clarifying their thinking and better expressing their own special knowledge. In a democratic country . . . . public support must be won if science is to get on. Public judgment of value is in the last analysis the final verdict. The education of the public is its largest social problem. To handle it from a more rational and less emotional point of view, people must be given at least the beginnings of a knowledge of the scientific method."

Contributors to This Issue

C. E. Lane received an A. B. degree from the University of Iowa in 1920 and an M. S. degree from the same university in 1921, and immediately joined the Engineering Department of the Western Electric Company, now Bell Telephone Laboratories. His first five years were spent in the Research Department engaged in general studies of acoustics pertaining to speech, hearing, and loud speaker development. Since that time he has been engaged in the development of transmission networks in the Apparatus Development Department. For some time he has been in charge of the group developing special filters.

After receiving the degree of B. S. in Mechanical Engineering from New York University in 1922, A. F. Leyden joined the Plant Department, entering the electrical engineering group. In 1924 he became head of that group, and two years later he took charge of the design and installation of the new power room in Basement B and the system for distributing its services through the new Section H. After a period devoted to the revision of shop order handling and office scheduling routines, he assumed charge of the plant construction group in 1929. In this capacity he supervised the design and installation of many recent plant projects, such as the chemical laboratories in 10-B, the welding and x-ray research laboratories in the basement, and the film processing equipment in Section L. Qualifications based on such experience earned him the Professional Engineering License from New York State in 1930. Two years ago he was assigned to act as the Laboratories' representative in connection with the New York Central Railroad alteration project.

E. J. Murphy received the B. Sc. degree from the University of Saskatchewan in 1918 and then continued his studies, first in engineering at McGill University, and later in physics at Harvard University. He joined the Chemical Laboratories in 1923, and for the following four years worked on the conduction characteristics of textiles. He has since been occupied with general studies of the properties of dielectric materials.

C. E. Lane

A. F. Leyden

E. J. Murphy

E. S. Savage

E. E. Schumacher

L. B. Hilton

After service as an artillery designer in the Ordnance Department of the United States Army during the World War, E. S. SAVAGE received the degree of B. S. in C. E. from the University of Texas in 1920. He then spent about two years in the Engineering Department of the Cleveland Twist Drill Company on the design of machinery for the production of small tools, and in 1923 he joined the Technical Staff of the Laboratories. At first he was engaged in design and development work on plugs, jacks, and similar manual central office apparatus. More recently he has been occupied with development work on fuses and protector blocks.

E. E. SCHUMACHER is a graduate from the University of Michigan. He entered the Research Department of these Laboratories in 1918 and for several years immediately thereafter was engaged with the development of vacuum tube filament. Since then his work has been primarily in the metallurgical field.

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