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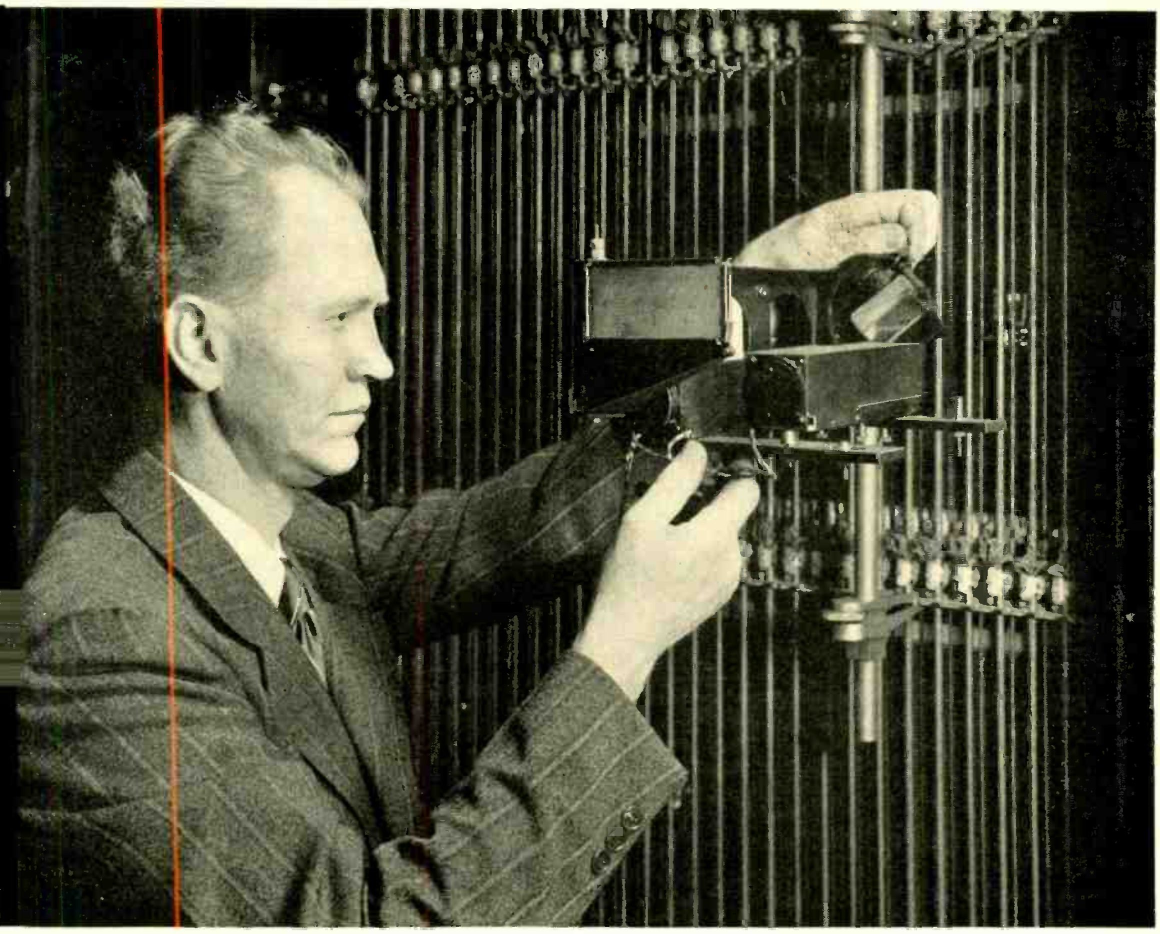


Measuring small relative motions in central-office switches

IARCH 1942 VOLUME XX NUMBER VII

Measuring Small Relative Motions in Central-Office Switches

By W. S. GORTON
Physical Research

SEVERAL years ago in an investigation of contact noise in panel switches, it became necessary to devise an instrument to measure the relative motion between a terminal of a panel bank* and the brush resting on it, since it was known that there was a certain degree of relationship between relative motion and contact noise. A close-up view of part of a panel bank and one of the panel brushes is shown in Figure 1. The terminals, on one of which the end of the pencil rests, are part of the rigid frame, but the shoe of the brush is held against the terminal by pressure of the flat spring. Vibration may cause a slight relative motion between brush and terminal, and it is this motion that is to be measured. The measuring device must be very small to fit in the small space available, and it must be very light so as to cause minimum interference with the motion of the brush. In the frontispiece to this issue, the small vibrometer is barely visible just to the right of the auxiliary optical system.

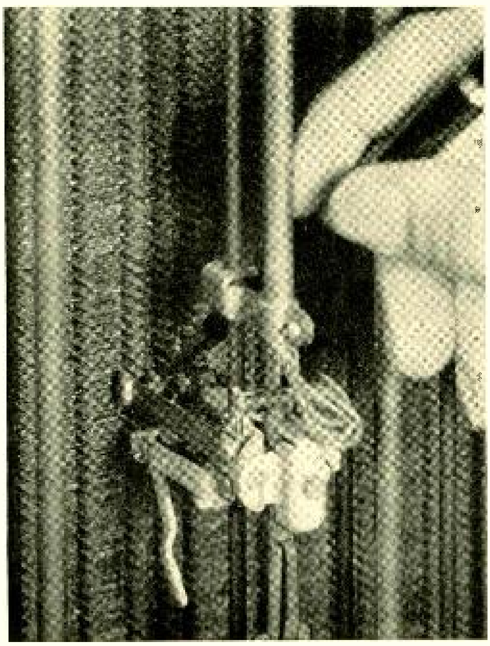


Fig. 1—Part of a central-office panel bank showing one multiple brush in contact with a set of bank terminals

The problem of measuring small motions has been met time and again in physics and engineering; a large number of instruments, mechanical, optical, and electrical, have been devised for the purpose, and were considered for the problem in hand. The instrument to be used had to indicate correctly the motion over the band of frequencies from 10 to 300 cycles per second, which had been observed in a previous study of absolute vibration, and, naturally, over as much wider a band as possible. Another important requirement was that the means used should be as insensitive as possible to electromagnetic disturbance. These requirements resulted in the choice of a mechanical device, with an optical lever that was developed to furnish part of the necessary magnification.

*Record, *October*, 1931, *page* 54.

After a consideration of the various mechanical means for amplifying small motions, the choice finally rested upon the principle of imparting the motion to be measured to one of two flat plates between which rolls a metal cylinder of as small a diameter as practicable. This device is mentioned in several places in the literature of physics but no account of its performance could be found. The method, however, had been used in previous work in the Laboratories, and its performance and a theoretical study of it indicated that it should be satisfactory for the purpose.

The instrument as finally developed and used in many hundreds of measurements in the telephone plant is shown schematically in Figure 2 and photographically in two forms in Figures 3 and 4. The latter measures the horizontal component of the relative motion, and the former the vertical. The base of the instrument is clamped to a group of terminals near the particular terminal to be investigated. The vibrometer proper is on ways and can be moved relative to the base by an adjusting screw which is manipulated by a special wrench. The finger that makes contact with the brush is attached to the upper plate or carriage, which is separated from the lower plate by two round arbors, approximately .015 inch in diameter. The carriage is held against the arbors by the S-shaped steel restoring springs, shown in Figure 2, which also furnish the force necessary to hold the finger against the brush. To one of the arbors is fastened a concave galvanometer mirror ¼ inch in diameter. Light from the straight-line filament of an incandescent lamp is reflected from the mirror and brought to a focus on a screen for visual observation, or

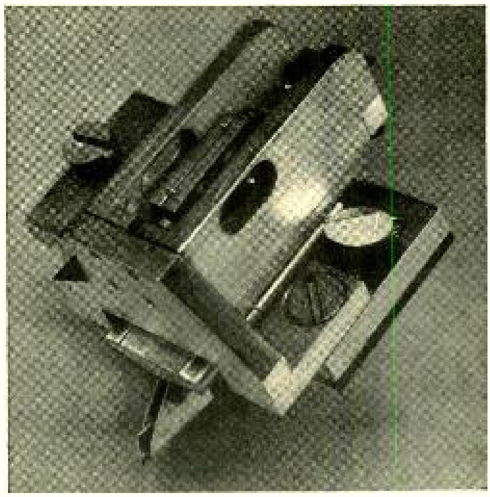


Fig. 3—Vibrometer for measuring vertical motion—about twice actual size

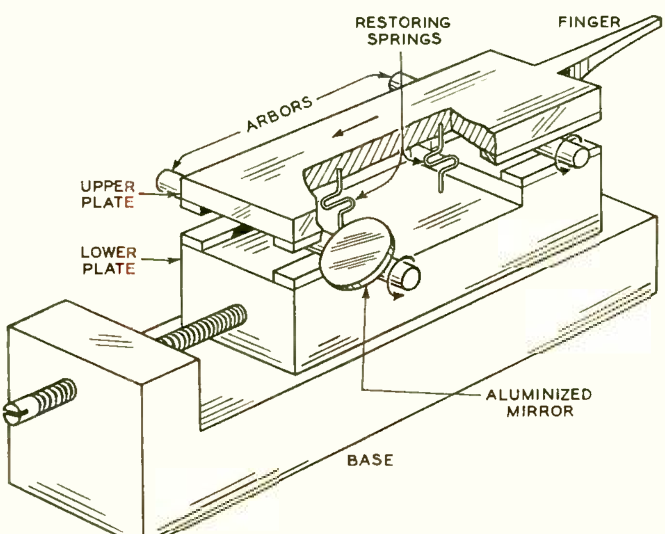


Fig. 2—Diagram of essential elements of vibrometer used for panel switches. The arbor of the vibrometer is only fifteen thousandths of an inch in diameter

on a revolving photographic film for graphic record. Magnification has ranged between 2,000 and 4,000 times in actual use.

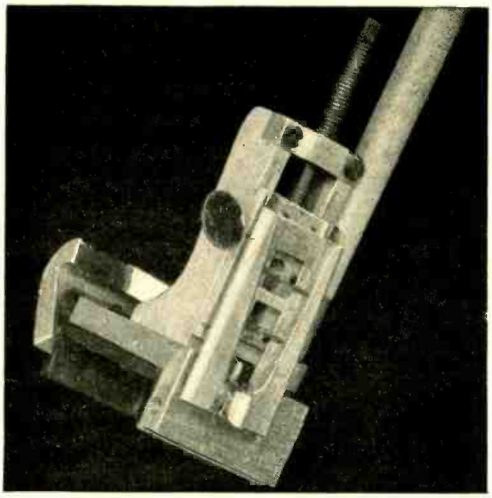


Fig. 4—Vibrometer used for measuring horizontal motion of panel switches—slightly more than actual size

Another form of the instrument, which was devised for measuring the relative motion between a step-by-step selector arm and its bank contact, is shown in Figure 9. The principle of operation is the same but the moving plate is curved instead of plane, and the arbor is held in place by the elasticity of the quadrantal carriage.

Wherever possible, the principal parts of the vibrometers are made of duralumin for lightness. Both plates of the "panel" vibrometers are shod with runners of flat clock-spring steel. The quadrantal carriage of the "step-by-step" vibrometer was formed from sheet steel and then hardened and tempered. The arbors presented a special problem. Drill rod carefully polished with the finest emery paper and crocus cloth in the usual way was not round enough. A special abrasive process had to be devised before satisfactory roundness could be secured. Various special tools were needed to handle the vibrometers, to put them in place on the panel bank, and to remove them from the panel bank. Some of these are shown in the accompanying illustrations.

The method generally employed for communicating the motion of the brush to the vibrometer is to press the finger of the carriage against the brush by turning the adjusting screw until the potential acceleration furnished by the restoring spring of the carriage is greater than the maximum acceleration of the brush. This results in the finger of the carriage always remaining in contact with the brush. The principle involved in this method is illustrated in Figure 5. The mass M attached to the spring S is deflected by the object B, the motion of which is to be investigated. The spring is potentially capable of imparting a certain acceleration to the mass M if the restraining force of the object B is removed. If this acceleration is always

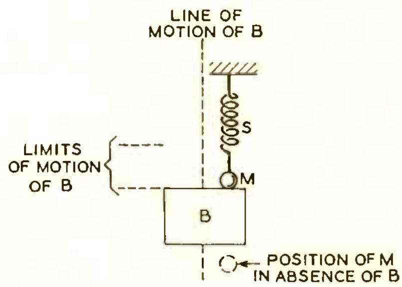


Fig. 5—By choosing the proper stiffness for the restoring spring S, *the vibrometer will remain in contact with the brush over the entire range of frequencies being studied*

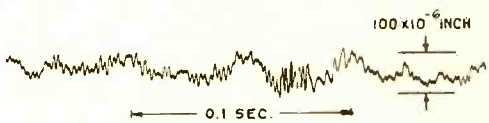


Fig. 6—Typical photographic record made with the vibrometer

greater than the maximum acceleration of B at any time in its motion, then B and M will always remain in contact. There is no necessary relation between the frequency of motion of B and the natural frequency of the mass M when B is removed. While the natural frequency of the panel vibrometer alone is of the order of ten cycles a second, the vibrometer follows faithfully frequencies at least as high as 900 cycles a second. A limit to this ability of a spring-supported mass to follow a vibrating object may be reached as the frequency of the motion approaches the natural frequency of the spring itself.

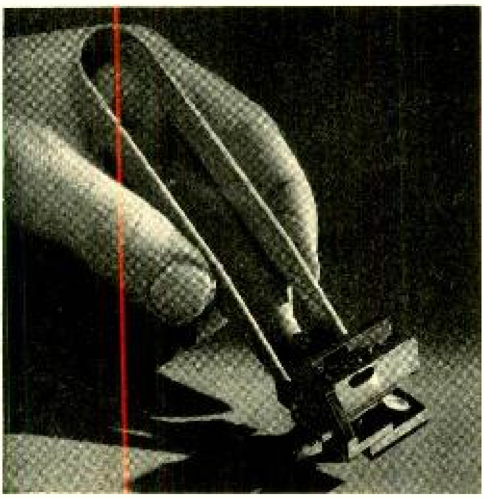


Fig. 7—The horizontal-motion vibrometer with special tool for putting it in place

To be able to dispense with the force (about one gram) necessary to secure adequate contact in the panel switch, a procedure was developed for cementing the finger to the brush. This process, including the necessary dissolving of the cement, while not as quick as the biasing spring procedure, was relatively expeditious. An investigation, however, showed that the force necessary to keep the upper plate in contact with the brush did not have any appreciable effect on the motion being investigated, and so the cementing method was not used for most of the studies.

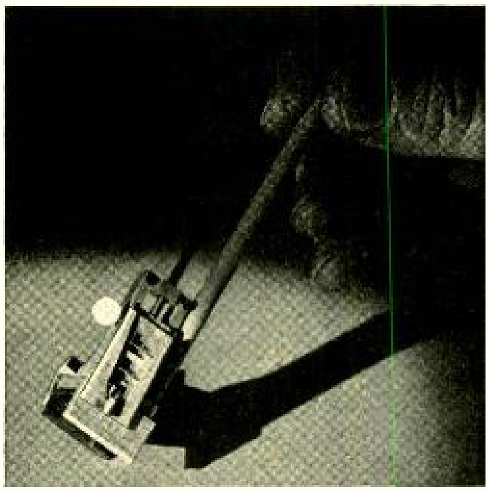


Fig. 8—Vertical-motion vibrometer with its mounting tool

The inertia of the moving system of the vibrometer is due chiefly to the moment of inertia of the galvanometer mirror, and amounts to about 0.9 gram. Its effect was estimated by noting the indications of the horizontal vibrometer both with and without the application of the vertical vibrometer, and of the vertical vibrometer with and without the horizontal one. It was found that the indications of one vibrometer were not affected by the presence of the other.

As used for visual observation in the telephone plant, the width of the image of the filament on the translucent screen was approximately .01 inch, and the width of a graduation on the scale was approximately the same. Under these circumstances a motion of one-fifth of the width of the line, that is, .002 inch, could easily be measured with the aid of a hand magnifier. Since the amplification used was always at least 2,000 times, motions of one-millionth of an inch could be seen and measured. This distance is approximately one-twentieth of a wavelength of visible light, which is about the limit of measurements of distance made by light waves. A photographic record of relative motion between brush shoe and terminal is shown in Figure 6.

Fig. 9—Step-by-step vibrometer

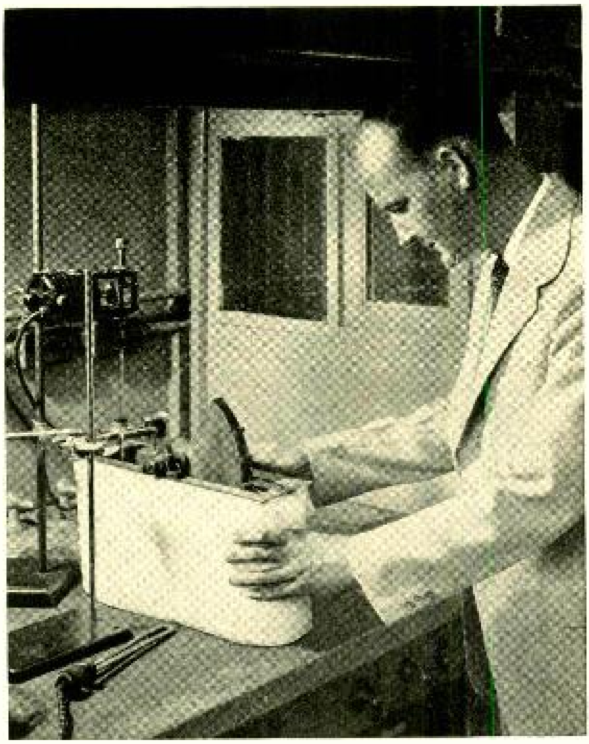
The overall performance of the instrument was investigated by driving it from a moving-coil loudspeaker motor actuated by a beat-frequency oscillator and power amplifier. Up to 1,000 cycles per second the performance was in accord with the simple theory outlined above. Calibration was effected by driving the vibrometer from a relatively massive tuning fork, which furnishes the purest obtainable sinusoidal motion. The amplitude was made as large as the vibrometer would permit, and was measured by a microscope. Several tuning forks having frequencies up to approximately 900 cycles per second were used, and the calibration was found to agree with the static one and also with that computed from the dimensions. Independent dynamic calibration was obtained from measurements made by light waves in a related line of work.

An important practical advantage of using an arbor rolling between two plates, where the motion is communicated by friction, is that not so much effort has to be expended in adjusting the relative position of the vibrometer and the object to be measured. If the mirror turns out not to be pointed in the right direction, it may be turned with a small pointed stick to bring it into the right position without the slightest harm to the instrument or detriment to the measurements. Another advantage arises from what at first sight might be judged a disadvantage, namely, the relatively sharp limit to the force of friction between the moving parts. When the acceleration of the carriage exceeds a certain amount (about three times the acceleration of gravity in the present vibrometers) the force of friction between the arbor and the plate is no longer sufficient to impart the necessary acceleration to the arbor, and the arbor slips and the mirror deflects irreversibly by a large amount. This unmistakable signal that the range of the vibrometer has been exceeded has been a valuable aid in insuring the reliability of the results.

The vibrometers have been used for many hundreds of observations, and photographic records have been made in important busy central offices in Manhattan. Much information on the motion and noise in actual working contacts under representative central-office conditions has been secured. What is perhaps fully as important is that it has been done without interfering with the operation of the offices in question.

Brittle Temperature of Rubber

By M. L. SELKER
Chemical Laboratories



INTEREST in the behavior of natural and synthetic rubber at low temperatures has grown considerably in recent years. Airplanes flying at very high altitudes and motor vehicles operating in arctic climates may encounter extremely low temperatures, and since both use rubber compounds, the need for precise knowledge of the behavior of rubber at low temperatures is essential. It has been known that rubber compounds become brittle at very low temperatures, but no published accounts have been found that give the effects of various factors on the brittle temperature for a wide variety of materials. Rubber is used primarily because of its insulating and elastic characteristics, and since the value of rubber insulation is largely lost if the material cracks under shocks at low temperature, the appearance of brittleness seriously affects the insulating power of the rubber as well as its elastic characteristics. The brittle temperature of the material thus determines to a large extent the usefulness of rubber and similar substances at low temperatures.

When crude rubber is held at a moderately low temperature for some days, say in the neighborhood of 14 degrees Fahrenheit (−10 degrees Centigrade), crystallization will occur. The rubber will get stiff and opaque, but will remain elastic to some extent; it can be stretched slightly and be bent without breaking. Well-vulcanized rubber does not crystallize, but as the temperature is lowered, it loses its ability to retract when stretched. If either crude or vulcanized rubber is cooled to some 70 or 80 degrees Fahrenheit below zero, however, it loses its elastic properties completely. If bent suddenly at right angles, it will break off very much like glass. It has been found that this transition to brittleness occurs at a sharply defined temperature, which is different for various natural and synthetic rubbers.

To assist in the study of the brittle temperatures recently made in these Laboratories, the simple apparatus shown in Figure 1 was constructed. A quadrant arranged to carry as many as six rubber specimens is mounted on a shaft, which may be turned with a simple crank, and is supported in a narrow, insulated tank into which acetone and dry ice, or other cooling solution, may be placed. The specimen to be tested is fastened to the quadrant and turned down into the cooling solution long enough for it to assume the temperature of the bath, which is determined by suitable thermometers. A quick rotation of the crank then brings the specimen sharply up against a rigid metal bar projecting from the edge of the tank toward the rim of the quadrant. If the brittle temperature has not been reached, the specimen will bend, but if it has, the specimen will break off cleanly. It has been found that the rubber becomes so tough at these low temperatures that considerable force is required to break it, and because of this only a single specimen is usually mounted on the quadrant.

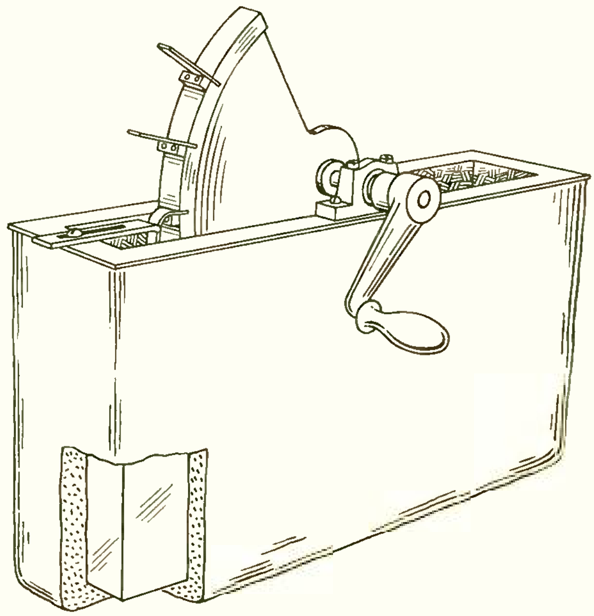


Fig. 1—Apparatus used in measuring brittle temperatures of rubber specimens

With this apparatus a series of tests were run on a wide variety of natural and synthetic rubbers. It was found that the brittle point of soft vulcanized rubber, which is about −75 degrees Fahrenheit (−59 degrees Centigrade), is essentially the same for all the vulcanizing periods common in industry. Certain of the synthetic mixtures show the same behavior. With rubber compounds vulcanized with an accelerator and a large amount of sulfur, or with sulfur alone, it was found that the brittle temperature varied nearly linearly as the amount of chemically combined sulfur. This is shown in Figure 2, which gives data for a rubber-sulfur stock and an accelerated stock.

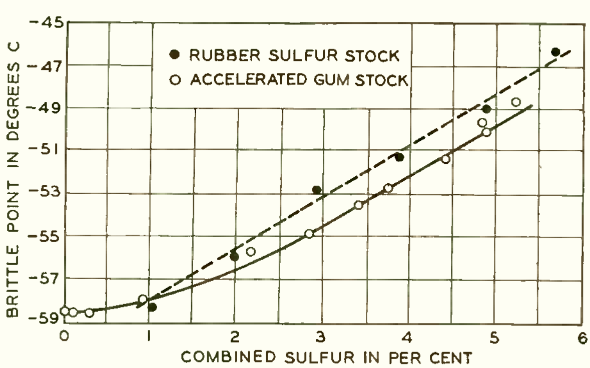


Fig. 2—Relationship between brittle temperature and percentage of combined sulfur

All the usual rubber compounds, the studies indicated, have brittle temperatures above that of crude rubber. Any addition of asphalt or resin, and of many oils, tends to raise the brittle temperature a few degrees. Zinc oxide and carbon black, however, can be added in large quantities with but small effect. The use of appreciable amounts of coarse fillers such as calcium carbonate, on the other hand, produces compounds with high brittle points after vulcanization. The various types of reclaimed rubber can be distinguished on the basis of their brittle temperatures, that from tire tubes having the lowest. Only two of the synthetic rubbers are comparable to natural rubber in elasticity at low temperatures. Synthetic rubbers also differ from natural rubber in having higher brittle temperatures than their compounds.

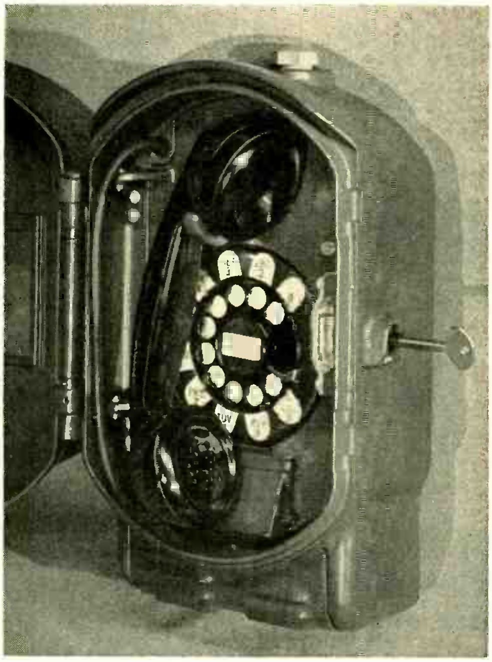
TABLE I—RELATIONSHIP BETWEEN BRITTLE TEMPERATURE AND MOLECULAR SIZE

Material	*Approx. Molecular Weight*	*Appearance*	*Temperature ° C.*	*Temperature ° F.*
Rubber	6,000	viscous brown liquid—solid	−48.0	−54
Rubber	30,000	masticated pale crêpe—soft, tacky	−61.5	−79
Rubber	100,000	pale crêpe—elastic solid	−61.5	−79
Polyisobutylene	1,500	viscous liquid	−23.0	−10
Polyisobutylene	10,000	very viscous liquid	−50.2	−58
Polyisobutylene	100,000	elastic solid	−50.2	−58
Polyethylene	low	soft, waxy	−15.0	+ 5
Polyethylene	high	tough, waxy but hard	−68.5	−91

There seems to be a relationship between brittle temperature and the size of the molecule of the substance. In general the large molecules have lower brittle temperatures than the small, but the change seems to be sudden rather than gradual, as is indicated by the data of Table 1. There seems to be a definite molecular size that must be attained before the brittle temperature characteristic of the material is reached. For rubber, this size corresponds to a molecular weight between 6,000 and 30,000, while for polyisobutylene it is between 1500 and 10,000. The difference between the brittle temperatures for large and small molecules may be very great, as exemplified by polyethylene, which has a brittle temperature of +5 degrees Fahrenheit (−15 degrees Centigrade) for small molecules, and −91 degrees F. (−68.5 degrees C.) for the large.

THE JOHN SCOTT MEDAL

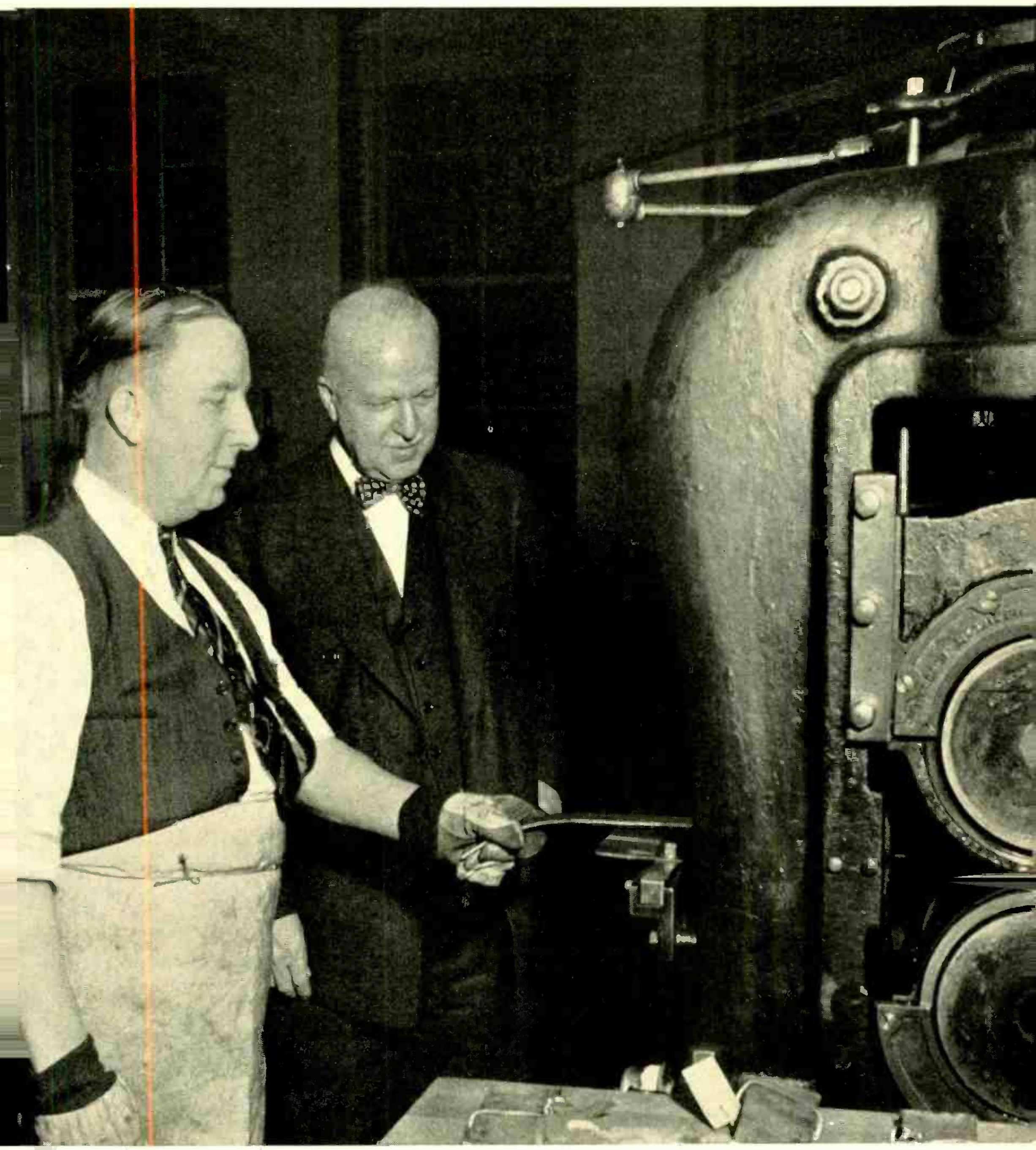
has been presented to Robert R. Williams, Director of Chemical Research, in recognition of his synthesis of Vitamin B_1*. Other present and former members of the Laboratories who have been similarly honored are H. D. Arnold, G. W. Elmen, W. D. Houskeeper and H. E. Ives.*



A Telephone Set for Exposed Locations

OUTDOOR telephone sets are now increasingly in demand for many different kinds of service in exposed locations. The recently improved 300G set shown here fulfills this requirement. It is easier to manufacture and has a longer operating life than previous outdoor sets. Standard handset, ringer and condensers are provided. The hinge of the self-closing door has been strengthened and cast iron has been used for the housing to conserve aluminum. There is a spring in the hinge to close the door automatically. A self-locking device that opens with a key is regularly provided but a lock which requires a key both to lock and unlock the case can also be furnished. The illustration below shows one of several types of these telephones being manufactured by the Western Electric Company at Hawthorne.

NEWS AND PICTURES



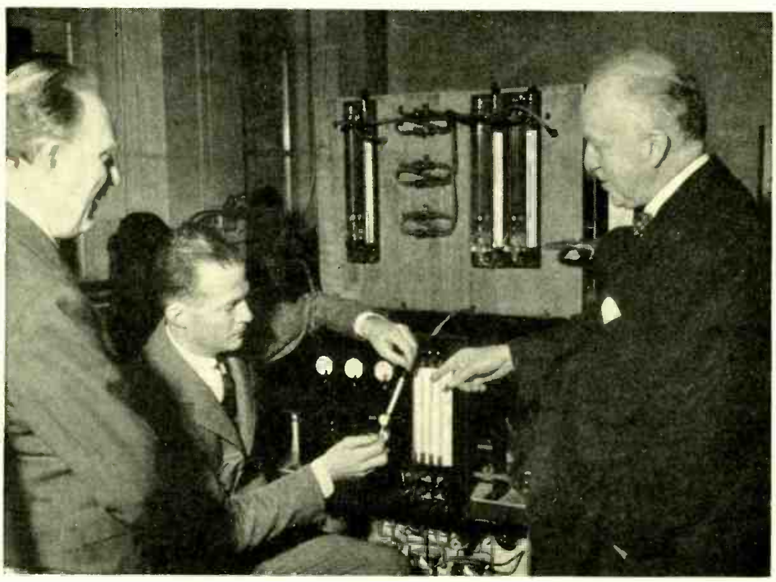
Walter S. Gifford, President of the American Telephone and Telegraph Company, watches R. J. Riley as he rolls a strip of permalloy on a cold mill in the metallurgical laboratory at Murray Hill

News of the Month

Bell System Executives Visit Murray Hill

An interested visitor to the Murray Hill Laboratory recently was Walter S. Gifford, President of the American Telephone and Telegraph Company. Accompanied by F. B. Jewett, O. E. Buckley and M. B. Long, he was shown a number of places of particular interest, each of which was explained by one of the men responsible for the work. The boiler house, the electric power sub-station and the water supply system were described by C. A. Chase. In the acoustics building, the auditorium and the large room later to be sound-deadened were shown by C. S. Haines, of the architects. Tea was served in the restaurant with E. V. Mace, plant operation manager, as host. In one of the partially finished laboratories J. G. Motley, construction engineer for the Laboratories, described the methods, developed under his supervision, for carrying pipe and wire services to the point of utilization. The Carbon Laboratory of the Physical Research Department was described and the work in progress was explained by F. S. Goucher and R. O. Grisdale. After a look at the Development Shop, the Medical Department, and one of the self-service stockrooms, the party proceeded to the Metallurgical Laboratory where one of the heavy rolls was shown in operation by D. H. Wenny and the Rohn mill, which will produce tapes as thin as 0.0002 inch, by Dr. Buckley. Equipment and projects of the Outside Plant Laboratory were described by R. A. Haislip.

Following the inspection, the party together with the heads of the departments concerned dined with Dr. Jewett at the Short Hills Club.

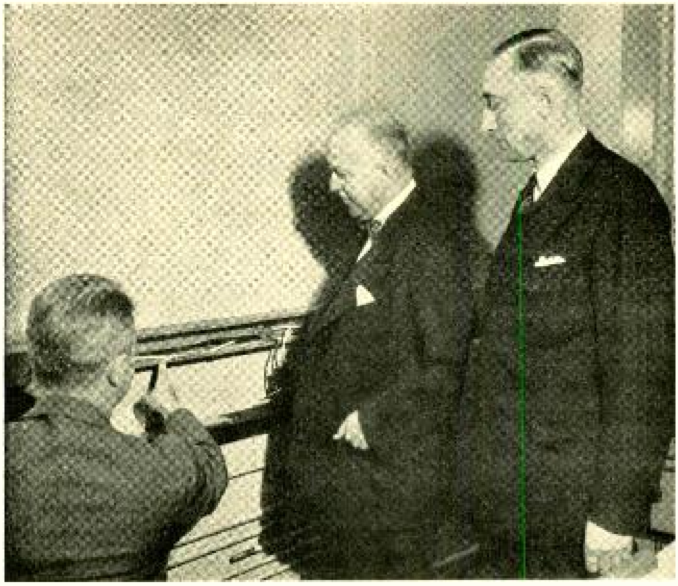


In the carbon laboratory of the Physical Research Department at Murray Hill Mr. Gifford discusses various experiments with R. O. Grisdale, center, and Dr. F. S. Goucher, left

Enrollment for First Aid Classes Is 270

Due to the importance of first aid treatment in civilian defense activities, 270 members of the Laboratories enrolled in the Spring Term of the Out-of-Hour First Aid Course. This has necessitated the formation of five classes, one for Advanced work and four covering the Standard Course. Classes are held each night, Monday to Friday, in the Club Lounge from 5:30 to 7:30 p.m.

There are 85 men and women taking the Advanced Course. This course, consisting of five two-hour sessions followed by an examination, is designed for those who have just completed the Standard Course and desire more instruction and practice in practical problems, and, in certain cases, for those who took the Standard Course some time previously and desire to bring their knowledge up to date. An Advanced First Aid Certificate, valid for five years, will be issued jointly by the Red Cross and the Laboratories to those who satisfactorily complete the course. L. E. Coon and W. F. Smith, Jr., are the instructors. The twenty-one assistant instructors in the four Standard Course classes act as group leaders.


J. G. Motley and M. B. Long explain to Mr. Gifford some of the Laboratory services available at Murray Hill

The other four classes, one for women and three for men, are taking the Standard First Aid Course of the American National Red Cross. This course develops a practical ability in rendering First Aid in cases of sudden sickness or accidents occurring in the home, on the street, and while at work, and consists of ten two-hour sessions followed by an examination.

Instructors for these classes are:

C. F. Benner	M. V. Hunter
F. B. Blake	Robert Pope
Katherine M. Doring	Harold Sagefka
J. M. Dunham	H. P. Smith
J. S. Edwards	L. C. Wescoat

The assistant instructors, who also act as group leaders in the Advanced Course, are:

Helen G. Adams	R. P. Jutson
T. M. Benseler	C. E. Kempf
P. G. Clark	A. C. Millard
J. R. Erickson	Margaret J. Portelroy
Georgine L. Fredericks	Ruth O. Robinson
G. H. Greb	A. H. Schafer
A. D. Hargan	H. B. Smith
W. M. Hill	E. W. Waters
I. L. Hopkins	I. V. Williams
A. L. Johnsrud	J. B. Worth

R. L. Young

The classes will be devoted to the study of wounds, burns, fractures and common emergencies, with demonstrations and practice in the control of bleeding, artificial respiration, and the application of dressings, bandages, and splints. A Standard First Aid Certificate will be issued to those who satisfactorily complete the course.

Consideration is now being given to the possibility of arranging another Advanced Class immediately upon the completion of the four Standard Classes.

Colloquium

At the January 12 meeting of the Colloquium, C. N. Hickman, retiring president, spoke on *Archery Paradise, Paradox and Paralysis*. Up until about twelve years ago, the velocity of an arrow had never been measured except by the use of a stop watch. During the last ten years the study of the internal ballistics of the bow and arrow has furnished a paradise for a number of physicists. Many of these fascinating problems were discussed by Mr. Hickman. For at least two centuries archers have tried to explain the paradox of how an arrow gets around the bow to hit the mark at which it is pointed. An explanation of this paradox was given, together with moving pictures taken at the rate of 4000 frames per second. Over fifty per cent of all archers, sooner or later, are stricken with what is often called paralysis or freezing. This interesting but aggravating affliction was discussed in detail from first-hand experience and methods of its prevention and cure revealed.

A. O. Jehle was appointed General Auditor of the Laboratories at the January 26 meeting of the Board of Directors

B. W. Kendall spoke on *Telephone Switching Systems* at the January 26 meeting. Mr. Kendall discussed the fundamental requirements and methods of switching telephone circuits; described the three systems standard in the Bell Telephone plant—step-by-step, panel, and crossbar; and compared these systems, giving the limitations of each.

A. T. & T. National Advertising

Informative copy is the backbone of A. T. & T. national advertising in 1942. Keyed to these crucial times, the advertisements stress the vital importance of telephone service and the character of the organization which renders it. As wartime needs require, pertinent information on the use of telephone services will be addressed to the public.

For Long Lines advertising, because conditions for the present make advisable the curtailment of long-distance promotion efforts, an informative approach is being used. Business papers will present the advantages of Classified Telephone Directory advertising for local merchants and of Trade Mark Service for national advertisers. In consumer magazines, the classified telephone directory is being publicized as America's buying guide. The college program will keep the business, industrial and professional leaders of the future informed of the aims, policies and accomplishments of the Bell System, together with advantages of Bell System employment.

"The Juicy Atom" Censored

In 1936, in a technical treatise discussing *The Theory of Magnetism* presented before students at Yale University and later published in the *Bell System Technical Journal*, K. K. Darrow said, "If I say that an orange consists of soft yellow juicy atoms, or that a marshmallow is made of sweet white sticky atoms, you recognize at once that those are not serious atomic theories: they are just futile and somewhat ridiculous statements." This phrase has since been made famous by being recorded on an endless steel tape and used on transoceanic radio circuits for lining-up purposes.

However, spy-conscious short-wave radio fans, some time before war took them off the air, were suspicious of the ethereal voice talking about atoms—soft yellow juicy ones and sweet white sticky ones. Was this an Axis fifth columnist's code? The matter was reported to the government and the newspapers. As a result, a new recording was made to correct the confusion and this now reads: "The following is a test transmission by a station of the American Telephone and Telegraph Company for circuit adjustment purposes. Magnetism is a quality which we attribute to the atom. We affirm that iron, nickel, gadolinium, gaseous oxygen, and in fact all substances, are magnetic because there is magnetism in their atoms." This is repeated over and over again until the distant technician has completed his job of lining up.

News Notes

Accompanied by O. E. Buckley, several other members of the Board of Directors visited the Murray Hill Laboratory on January 28. Those present were C. F. Craig,

The Laboratories have qualified as an issuing agent for Defense Savings Bonds purchased under the Payroll Allotment Plan. In this photograph the first group of bonds is being prepared for issuance on an addressograph machine. Left to right: J. Gris, Daniel Spicciati, F. W. Seibel, R. F. Newcomb and G. B. Small. Albert Vabulas is operating the machine

C. G. Stoll, W. F. Hosford and J. M. Bancker. They were met by M. B. Long, who with E. V. Mace and J. G. Motley, showed them a number of points of interest in the buildings.

Leaves of absence for military service have been granted to Frank J. Fleischer, United States Maritime Commission Academy, Great Neck, New York, and to John C. Roe, Second Corps Area Headquarters, New York City.

K. J. Ogaard, who returned from army service some months ago, has been recalled to active service and is now at Camp Upton.

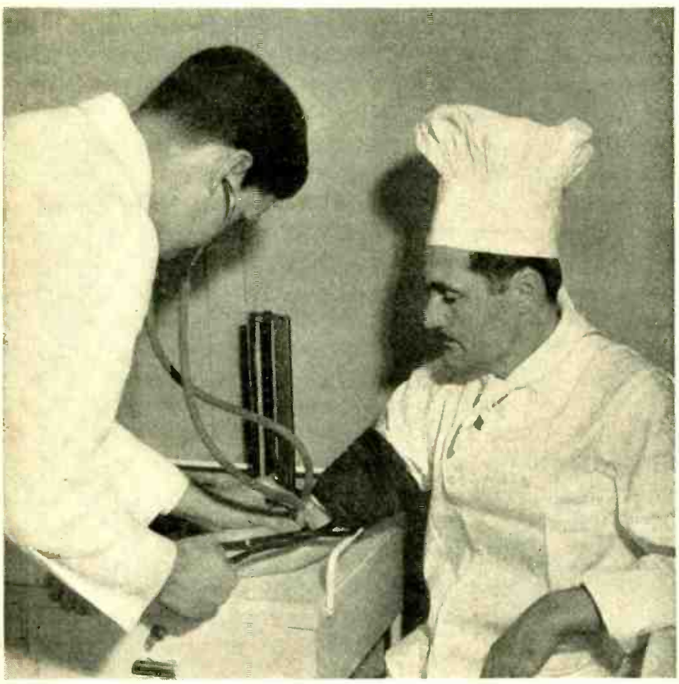
Many members of the Laboratories attended the winter convention of the Institute of Radio Engineers held in New York from January 12 to 14. In addition to the

William H. Harrison, left, and Donald Nelson, War Production Board chief. Of Mr. Harrison, named to head the Production Division of the newly formed Board, Mr. Nelson has said, "I bear a great deal of confidence in him. He is hard enough, and tough enough, to see a good production job done, and the bottlenecks cut through"

The Medical Department at Murray Hill

Dr. Orrin F. Crankshaw is on duty from 10:00 *to* 12:00 *every morning and available on call at other times*

The receptionist is Martha Schmitt, w. takes care of the medical and personn records at Murray Hill



During a periodic physical examination, made on all persons who handle food, Dr. Crankshaw checks the blood pressure of Otto Mohni, head cook of the restaurant

Miss S. Crawford (right), full-time nurse at Murray Hill, in the medical laboratory address of F. B. JEWETT on *The Mobilization of Science with Special Reference to Communication*, a three-page abstract of which was published in the last issue of the RECORD, papers were presented by W. G. SHEPHERD and R. O. WISE on *Variable-Frequency Bridge-Stabilized Oscillators* and by W. P. MASON and I. E. FAIR on *A New Direct Crystal-Controlled Oscillator for Ultra-Short-Wave Frequencies*. At the annual banquet diplomas were presented to Mr. Mason and G. E. SOUTHWORTH who became Fellows of the Institute. Serving on various convention committees were H. A. AFFEL, chairman of the *Papers Committee*, F. A. POLKINGHORN, *Registration*, and P. B. FINDLEY, *Publicity*.

Major Andrew W. Clement of the Coast Artillery Board in front of his quarters

Ensign R. A. Kempf is Communications Officer reporting to Chief of Naval Operations

RALPH BOWN gave a non-technical discussion before the January 9 meeting of the Radio Colloquium held at the Holmdel Radio Laboratory on his experiences during his recent "Clipper" trip to Europe which was made at the request of the National Defense Research Committee.

KARL K. DARROW spoke on *The Concept of Entropy* before the Physics Colloquium of Brown University. He discussed *Physics and Chemical Forces* before the Brown University chapter of Sigma Xi; before a joint meeting of electrical, radio and illuminating engineers sponsored by the University of Cincinnati student branch of the A.I.E.E.; before the Physics Colloquium of Washington University in St. Louis; and before the New York Electrical Society.

Write to Our Men in Service

Next to mess call, there is nothing so welcome to a man in the service as a letter from someone who knew him back home. Latest addresses can be secured by dropping a note to Benefit Plan Operation, West Street Mail.

R. M. BURNS visited Princeton, New Jersey, to interview prospective employees. Mr. Burns was also at the Western Electric Company in Hawthorne on various chemical matters.

C. S. FULLER visited the Hawthorne plant of the Western Electric Company to discuss the use of thermo-plastics for telephone sets.

C. J. CHRISTENSEN was also in Hawthorne regarding the production of quartz crystals.

H. W. HERMANCE visited the Brandywine central office at Pittsburgh in connection with establishment of experimental cleaning practices for panel-bank contacts. Mr. Hermance has been appointed a Councilor of the New York section of the American Chemical Society.

L. H. GERMER presented a paper entitled *Electron Diffraction Studies of Order in Copper-Gold Alloys* before a joint meeting of the Pittsburgh chapter of the American Institute of Mining and Metallurgical Engineers and the Pittsburgh Science of Metals Club.

As THE THIRD LECTURE in the *Symposium on Non-Linear Circuit Theory*, sponsored by the Basic Science Group of the New York A.I.E.E. section, W. R. BENNETT discussed *Fourier Series Solutions*.

TWO PAPERS by members of the Laboratories were presented at a meeting of the American Wood Preservers Association held in Minneapolis on January 26. They were *Greensalt—A New Preservative for Wood* by W. McMAHON, C. M. HILL and F. C. KOCH and *Greensalt Treatment of Poles* by G. Q. LUMSDEN and A. H. HEARN.

F. F. LUCAS discussed *High-Power Metallography* before the Syracuse chapter of the American Society for Metals.

HENRY HOVLAND RETIRES

Henry Hovland

HENRY HOVLAND of the Systems Development Department retired on February 28 after over forty-one years of service in the telephone industry, both independent and Bell System. After studying at the University of Minnesota he joined the Nicollet County Telephone Company in Minnesota in 1900 where he assisted in the installation of an automatic dial system in Jaylord, Minn. Three years later he became associated with the Automatic Electric Company in Chicago and for the next six years was chiefly concerned with field work—checking telephone installations and training the operating personnel.

In 1909, two years before the A. T. & T. acquired control of the Lincoln Telephone and Telegraph Company, Mr. Hovland joined the latter where he became supervisor of maintenance. He came to West Street in 1913 and, in the Systems Development Department, took part in the trial installations of panel-type selecting equipment at Newark and Wilmington. Later he engaged in the development of circuits for private branch exchanges employing dial systems. More recently he has been associated with the development of circuits for step-by-step central offices. An article by Mr. Hovland, describing the facilities for handling large PBX trunk groups in step-by-step areas, was published in the September, 1941, issue of the RECORD.

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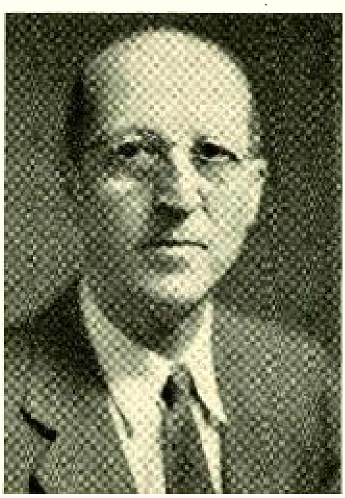
HARRY W. MACDOUGALL *of the Patent Department completed forty years of service in the Bell System on February 5*



RAY S. HOYT *of the Technical Consulting Staff completed thirty-five years of service in the Bell System on February 22*

G. M. BOUTON has been appointed a member of a special advisory committee of metallurgists which will assist metal-producing or metal-working manufacturers engaged in war production. The committee was formed by the New York chapter of the American Society of Metals and is known as the War Products Advisory Committee.

THE WINTER CONVENTION of the American Institute of Electrical Engineers was held in New York from January

William T. Booth
of the Transmission Apparatus Development Department completed thirty-five years of service on Feb. 17

David D. Haggerty
of the Personnel Department completed thirty-five years of service in the Bell System on February 9

Low visited the Hawthorne plant of the Western Electric Company to discuss the manufacture of experimental switching apparatus.

C. Erland Nelson was in Pittsburgh in connection with panel-bank contact studies.

J. D. Tebo of the Laboratories and H. G. Mehlhouse of the Western Electric Company presented a paper, *Some Mechanical Aspects of Telephone Apparatus*, before the Detroit Section of the A. S. M. E. in Detroit on February 3.

J. W. Kennard and L. M. Gambrill of Point Breeze were in Murray Hill in connection with the development of toll cable facilities and testing problems.

26 to 30. While no formal papers were presented by members of the Laboratories, many attended the various technical sessions and participated in some of the special conference meetings arranged to discuss pressing questions, particularly the conference which was devoted to the subject of the use of substitute materials in the communications industry.

C. D. Hocker attended the Executive Committee meeting of the American Society for Testing Materials held in Philadelphia on January 20.

W. T. Booth, N. Y. Priessman and M. A. Froberg were at the General Electric Company at Lynn, Mass., in connection with problems of supply of selenium rectifiers. They also visited the plant of the Aerovox Corporation, manufacturers of electrolytic condensers, at New Bedford, Mass.

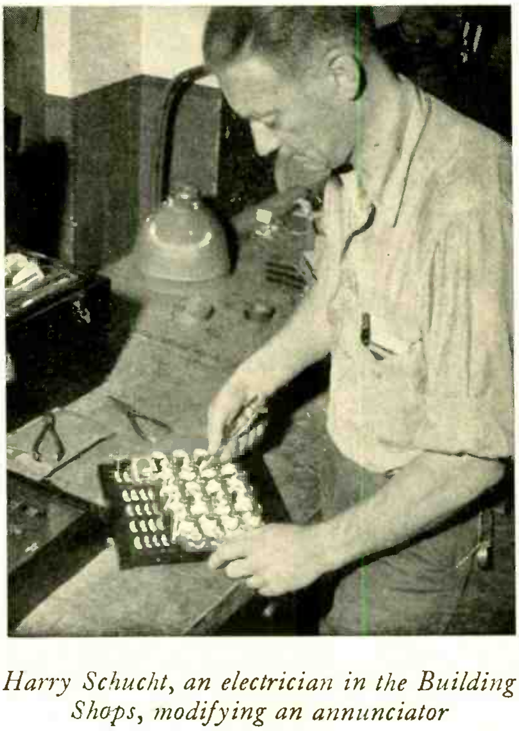
P. B. Drake visited New Haven in connection with a step-by-step apparatus maintenance problem.

J. R. Townsend, on February 12, spoke on *Plastics* before a group at the Newark College of Engineering.

R. Nordenswan and G. H. Downes were in the New Haven offices of The Southern New England Telephone Company regarding the use of pressure cleaning equipment.

H. O. Siegmund, I. S. Rafuse, and F. K.

C. A. Webber visited the Point Breeze plant of the Western Electric Company to discuss cord development problems. He also visited Hawthorne where he conferred with various engineers on problems of wire.



Harry Schucht, an electrician in the Building Shops, modifying an annunciator

The Library at Murray Hill

Dorothea Charlton, above, is in charge of the Library at Murray Hill. H. T. Reeve and D. H. Wenny are at one of the periodical tables

C. D. Hocker, above, looks ove an article in a current periodica which Barbara Vatter has lo cated for him

T. C. Henneberger, left, usin one of the study carrells

C. H. Amadon has recently visited the Philadelphia, Harrisburg and Pittsburgh headquarters of The Bell Telephone Company of Pennsylvania for conference discussion and field demonstration of approved methods of inspection and appraisal of wood poles that are in service.

D. M. Osterholz obtains a coil from stockkeeper H. A. Hesch in the Graybar-Varick tenth-floor stockroom

On a recent trip to Minneapolis and Chicago R. H. Colley and R. C. Eggleston discussed with pole and crossarm manufacturers and suppliers the production and treatment of cedar poles. Proposed changes in the design of crossarms were also presented and studied.

A. J. Kizelevich measuring the capacitance and conductance of 400-type condensers in the coil-test room of the Development Shop

J. G. Segelken went to Norfolk in connection with engineering studies that are being made of the commercial kiln drying of southern pine poles.

S. C. Miller attended a meeting in Philadelphia on January 14 of the section on lead coated hardware, American Society for Testing Materials, Subcommittee VI of Technical Committee A-5.

Members of the Laboratories to Whom Patents Were Issued During the Month of January

H. H. Abbott	S. J. Harazim	H. A. Lewis	V. L. Ronci
H. M. Bascom	J. B. Harley	F. B. Llewellyn	V. E. Rosene
J. Baumfalk	G. Hecht	A. A. Lundstrom	H. H. Schneckloth
H. I. Beardsley	R. E. Hersey	W. P. Mason	K. D. Swartzel, Jr.
R. B. Blackman	W. H. T. Holden	H. J. McSkimin	R. J. Tillman
L. J. Bowne	J. D. Hubbell	P. B. Murphy	A. Tradup
H. Eckardt	W. F. Kannenberg	F. A. Polkinghorn	C. W. Vadersen
J. O. Edson	B. J. Kinsburg	W. A. Rhodes	L. Vieth
O. C. Hall	B. F. Lewis	G. H. Rockwood	J. M. West
C. W. Halligan			C. F. Wiebusch

Some Members of the Laboratories

Biographies of members of the Laboratories chosen by lot from those who have been with us more than six months and less than twenty-one years follow.

* * * * *

A hundred per cent Laboratories home is that of George W. Meszaros, of Toll Equipment Development, since Mrs. Meszaros is in the Equipment Drafting Department at the Davis Building. Their acquaintance began here, and they were married three years ago.

After graduation from Stuyvesant High in 1926, George entered the Systems Drafting Department, where he prepared new drawings specializing on wiring diagrams. He has recently completed evening session courses at City College which have earned him a B.E.E. degree. In 1939 he joined the Trial Installation group and helped in the engineering and installation of the radio telephone system for emergency vehicles at 32 Sixth Avenue, the K2 carrier telephone installation between New York and Pittsburgh and the program on K carrier installation between New York and Boston. Shortly thereafter he worked in the Current Development Group analyzing special problems in connection with Western Electric carrier telephone installations. Last year he transferred to the Toll Equipment group where he assisted in the development of the 3C Teletypewriter Switchboard. He is now in the Power Plant Development group doing his part in the war effort of the Laboratories by developing power plants for the armed forces.

Many interests contribute to George Meszaros' life. For several years he has been a member of the Bowling League and of the Stamp Club. In the summer, his recreations are tennis and swimming; in the winter he collects stamps and breeds tropical fish in his uptown apartment.

* * * * *

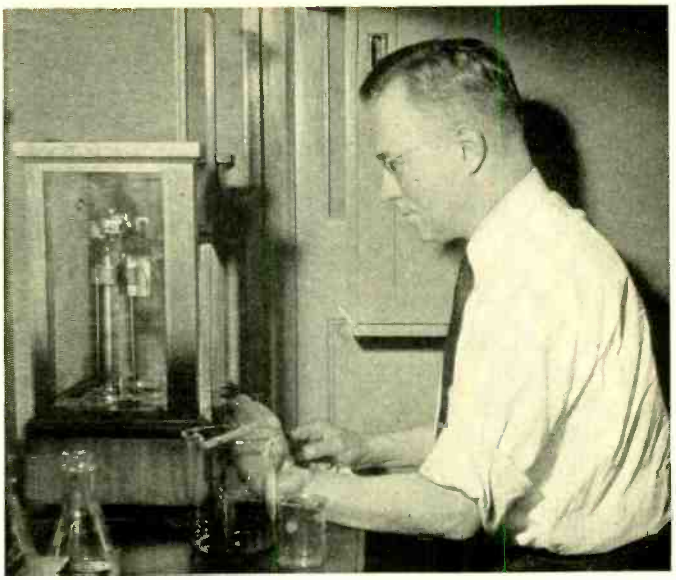
Herb Salch's work is a good index of the activities of the Laboratories, for across his desk and his partner's flow all the orders to replenish stocks of materials. In busy times like the present the two, Herb and Eddie Collins, handle approximately 100 orders a day. When the stock of any item is nearing the re-ordering point the record card goes to Herb or Eddie. After making certain calculations based on past performance, the theory of probability, etc., they determine the most economical amount to order. From this information posted on a stock purchase card the Purchasing Department is authorized to place the order on the supplier.

Born in West Hoboken, Herb attended local schools and graduated from Dickinson High School in Jersey City in 1922. Then entering the Laboratories, he was soon transferred to apparatus information, where he cared for the stock of "Y-models." Those are samples of all sorts of apparatus made in the Laboratories for test, and frequently

George W. Meszaros

drawn out by engineers for further study. Herb became so well known as "librarian" of the collection that some of his acquaintances still think of him as the man to call about Y-models. Actually, he has been in the Stock Control group since 1935.

In Secaucus, where he and Mrs. Salch live now, Herb is superintendent of a Sunday School and an exempt fireman. He used to play baseball on his department's team in the Laboratories league, but now between his work and his two boys — five and one-and-a-half years respectively — he finds time and energy for no games more strenuous than "horseshoes."



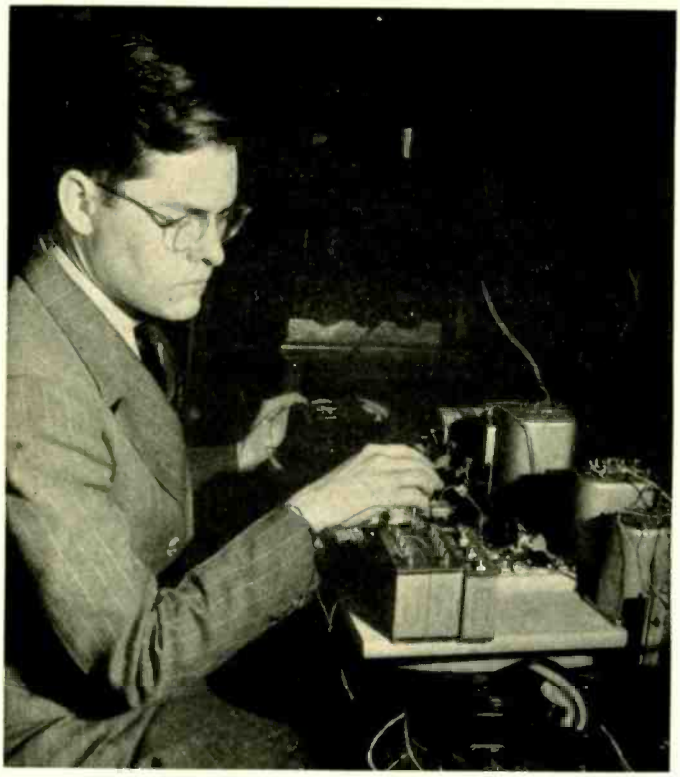
Jens F. Jensen

* * * * *

As SOON AS HE GRADUATED from Perth Amboy High School, Jens F. Jensen began his career as an analyst by getting a job in the assay laboratory of American Smelting at Perth Amboy. That was in 1910; during the next five years he took evening courses at Pratt and Brooklyn Polytechnic. Then his profession took him to a copper smelter in Peru; he gave that up to serve in World War I, and was mustered out as a Second Lieutenant. After two years at a silver mine in Mexico he came back to New York where in the research laboratory of Guggenheim Brothers he studied the refining of low-grade tin ores.

In 1929 Mr. Jensen became a Member of the Technical Staff in our general analytical laboratory. This group contributes to our work by determining the constituents of a great variety of materials. Sometimes they have a good idea of what is in the sample, in which case the early steps of an analysis are obvious. Often, however, results are conflicting; or the physical properties are not explained by the apparent chemical constitution. That is where Mr. Jensen's long experience is so valuable. Among his recent analyses have been wood preservatives, alloys, and proposed substitutes for zinc and nickel as protective coatings. He has also contributed materially to the Laboratories' work on the development of standard techniques for analysis.

Herbert W. Salch



Sherwood King

M. V. HUNTER visited Mt. Holly, N. J., in connection with the installation of an emergency power supply for calculagraphs.

D. VANMETER was in Lowellville, Ohio, to supervise the installation of new facilities in the step-by-step community dial office.

C. H. ACHENBACH and V. T. CALLAHAN visited gasoline engine manufacturers in Chicago and Minneapolis. Mr. Callahan also visited manufacturers at Canton, Ohio, and Lansing, Michigan.

J. H. SOLE is at Fort Wayne, Indiana, on machine design.

C. S. KNOWLTON was at Wright Field in Dayton and the General Electric Company in Schenectady on power machine problems.

F. T. FORSTER observed battery operation at Washington.

A. J. WIER and F. A. BROOKS, at Philadelphia, inspected a new model of the Leeds and Northrup controller, which is used in the gain regulators of the type-K carrier telephone system.

A. C. THOMPSON and B. MCWHAN spent most of January in Baltimore testing the a-c key-pulsing equipment installed in the No. 1 toll switchboard that will complete connections into No. 1 crossbar dial offices. B. MCKIM and L. M. ALLEN also made short visits to Baltimore on this project.

G. A. HURST spent several weeks in Jonesville, N. Y., testing the No. 380 crossbar unattended dial office.

In Summit, where Mr. and Mrs. Jensen live, they have a daughter in senior high school and a son in junior high school. At one time, Mr. Jensen played softball on the "Bell Labs" team of the Summit League; he still plays tennis. At present he is a member of the advisory council of a nearby recreation center.

* * * * *

BEFORE SHERWOOD KING graduated from Harvard (B.S. '38), and particularly while he was doing graduate work at Lafayette (M.S. '40), he had his eye on the Laboratories, so he took all the courses that bore on communication. After a few months under training in the switching laboratories, he was transferred to the toll transmission group where he is now developing equipment for national defense.

Like many another young Laboratories couple, the Kings live in the Village. When the war emergency and his Out-of-Hour Courses leave him time for recreation, he enjoys photography.

TWENTY-FIVE-YEAR SERVICE ANNIVERSARIES

J. B. KELLY, well known for his work on audiometers and audiphones, first worked for the Bell System during summer vacations while attending Pennsylvania State College. Following his graduation with the degree of B.S. in Electrical Engineering in 1917 he immediately entered the Engineering Department of the Western Electric Company. With the Research Department he was engaged for several years in studies of the quality of telephone transmission. In 1924 he began his work on the development of audiometers and audiphones for the hard of hearing. As part of this work, a considerable portion of his time was devoted to the problem of measuring children's hearing in public schools.

Late in 1935 Mr. Kelly became executive assistant to the Physical Research Director. Four years later he transferred to the Specialty Products Division of the Western Electric Company where he was engaged in sales promotion problems in connection with hearing aids and audiometers. In this he worked closely with the Laboratories, audiphone dealers and members of the medical profession. In June, 1940, he returned to the Laboratories and after a year with the Bureau of Publication transferred to the acoustical group of the Physical Research Department. At present, in addition to certain fundamental acoustical studies, he is associated with a study sponsored by the National Research Council to evaluate the effectiveness of a high-quality group-hearing aid in schools for the hard of hearing; and with another study under the same sponsorship to investigate the application of audiphones to children with impaired hearing in the public schools.

C. E. Ramsbotham

J. B. Kelly

Every vacation finds the Kellys, who live in Queens Village, Long Island, roaming around some part of the North American continent. Last summer they made an extensive automobile tour of Mexico. As a recreation Mr. Kelly plays golf. He is a member of the Telephone Pioneers of America.

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Most of C. E. Ramsbotham's service with the Laboratories has been in the Patent Department. After a few years in the Accounting Department, mostly on special studies, he transferred to the service group of the Patent Department and then to the group making routine studies of all patents issued that were in any way concerned with the telephone industry. Since 1929 he has been primarily concerned with the preparation and prosecution of patent applications covering general equipment such as handsets, resistances, variable condensers, train dispatching and clock systems and other apparatus and systems.

Before joining the Bell System Mr. Ramsbotham had worked for thirteen years with other companies. He spent twelve years with the brass, iron and steel firm of McNab and Harlin Manufacturing Company in Paterson, N. J., particularly on plant engineering and operating phases including cost analysis and estimating. Following this he then spent a year in the New York office of the Canadian Inspecting and Testing Laboratory of Montreal.

The Ramsbothams live in Mountain View, N. J., and have a daughter who is a trained nurse at St. Vincent's Hospital in Montclair and a son who is a senior in high school.

* * * * *

A. A. Mayer joined the Engineering Department of the Western Electric Company in 1917 and shortly thereafter went into the circuit laboratory, where he was engaged in contact metal studies. Following this he tested manual and toll circuits in this laboratory and then in 1920 transferred to similar work in the panel laboratory. He studied at the College of the City of New

A. A. Mayer

H. R. Clarke

York and in 1925 received his B.S. in Electrical Engineering.

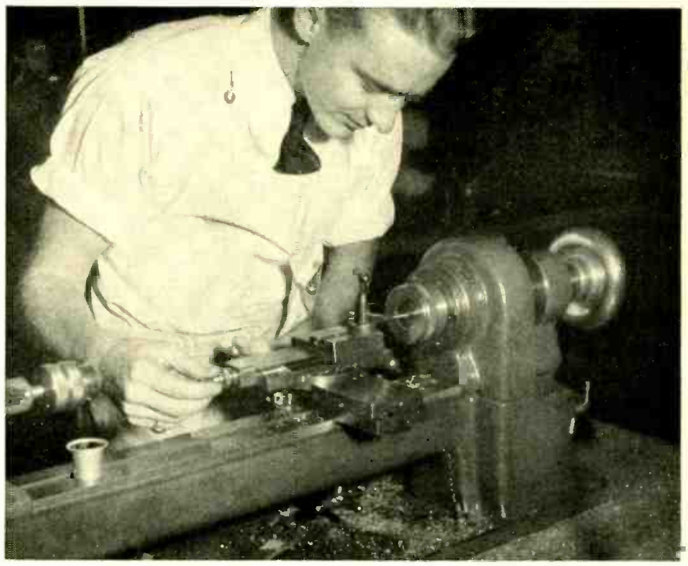
Since 1923, in what is now the Switching Development Department of the Systems Department, Mr. Mayer has been concerned with the preparation of practices covering the requirements and adjusting procedures of all central-office apparatus. At present he is engaged in the preparation of similar practices covering tests of the various circuits used in the crossbar system.

The Mayers live in the Flatbush section of Brooklyn with their seven-year-old boy.

* * *

For seven years before H. R. Clarke joined the Bell System in 1917 he did engineering work, first with the Ellis Adding Typewriting Company, then with the Public Service Electric Company of New Jersey, the Crucible Steel Company, and finally as a member of the firm of Andrus, Kramer and Clarke Engineering Company. During these years he took evening courses at the Newark Technical School from which he graduated in 1915. His first work at West Street was in the radio group on the development of wind-driven generators for aircraft. Shortly after World War I he entered the Specifications Department on its formation where he prepared manufacturing information covering all types of telephone apparatus.

Since 1922, in what is now the Station Apparatus Development Department, Mr. Clarke has been intimately concerned with the development of station apparatus, including transmitters, receivers, handsets, mountings, headbands and testing equipment on which he has been granted twelve patents. He was associated with the original design of the handset handle on which he holds a patent covering the mechanical and electrical interlinkage to prevent howling. Much of the work on the lineman's rubber handset, described in the November, 1941, issue of the Record, was done by him. Mr. and Mrs. Clarke live in the South Mountain section of Milburn, New Jersey, where he has a well-equipped shop, both machine and woodworking, for home experimentors as well as a hobby for himself. Mr. Clarke is a Telephone Pioneer.



Walter Whinn turning a steel shaft in a bench lathe in the Development Shop

C. H. McCandless spent several days in Chicago to attend the cut-over of the Rogers Park crossbar office where 28,650 lines were installed.

L. J. Stacy has made further visits to New Haven in connection with the study of dialing in step-by-step areas.

F. R. Lamberty was in Washington in connection with new private-branch exchange facilities recently made available for the War Department and the O.E.M.

Robert Pope attended a meeting of the Cathodic Section of the Petroleum Industry Electrical Association in Kansas City on January 15 and 16. Co-operative methods of preventing corrosion on very long pipe-buried structures were discussed.

International News Photo

When G. H. Downes of the Facilities reported at his Selective Service headquarters to register, across the table from him was Mrs. Downes, a volunteer draft worker. She asked him all the stock questions and noted down his answers

B. A. Merrick attended a meeting in Philadelphia on January 12 of the Section on Galvanized Hardware, American Society for Testing Materials, Subcommittee VI of Technical Committee A-5.

H. G. Jordan and P. F. Jones participated in tests of the type-K2 carrier telephone system between New York and Pittsburgh.

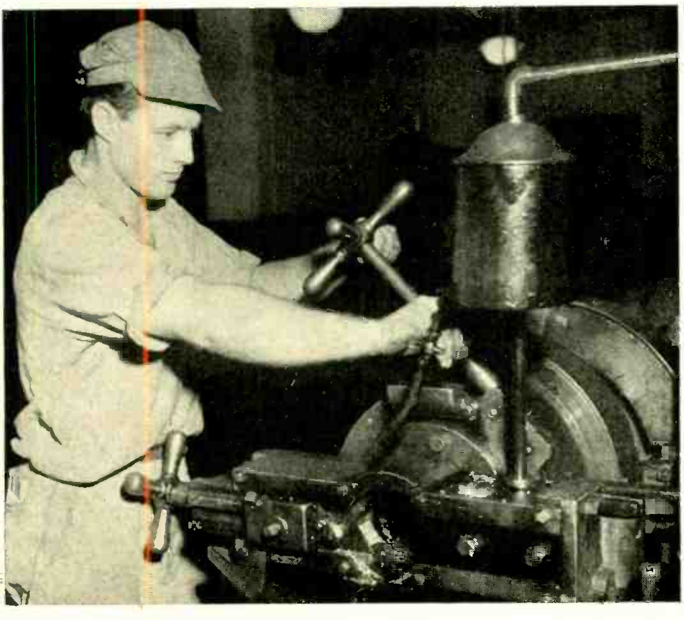
E. F. Vaage has been in Allentown and Pittsburgh in connection with the trial of the type-K2 carrier system.

A. J. Aikens, G. H. Baker, L. B. Hochgraf and R. J. Symonds conducted crosstalk tests at Ligonier, Altoona and Lewistown, Pa.

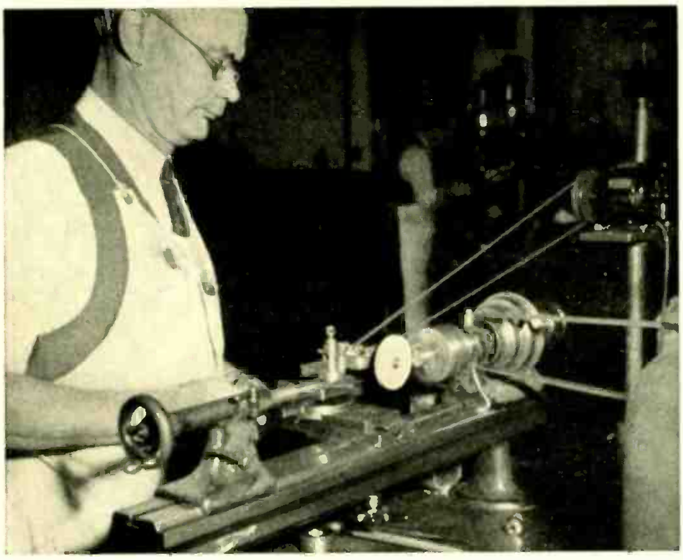
R. J. Symonds and R. S. Tucker took part in radio interference tests at Sands Point, N. Y.

M. Aruck and D. F. Hoth conducted noise investigations on local circuits in northern New Jersey.

E. S. Wilcox, C. O. Cross, C. H. Gorman and H. Kahl were in Nebraska and Colo-



William Weiler threads a piece of three-inch pipe in the Building Shop in Section H



Frank Wallenius in the Precision Room of the Development Shop grinding a plunger for a mold

rado making crosstalk tests on the Omaha-Denver toll cable.

H. B. NOYES completed crosstalk tests on the San Francisco-Oakland cables and returned to New York.

B. C. GRIFFITH and W. C. BALL spent a few days in Baltimore on noise studies in connection with the 0.8-mc coaxial system.

SINCE THE MIDDLE OF DECEMBER the New York-Philadelphia coaxial cable has been in limited commercial service and has been operating without trouble. Forty-eight telephone circuits are now routed through this cable system.

J. W. SCHMIED and W. F. SIMPSON attended a hearing before the Primary Examiner in interference proceedings conducted at the Patent Office in Washington.

R. A. DELLER has been spending part of his time in Washington with the War Production Board assisting that organization in obtaining the services of men with special training and experience.

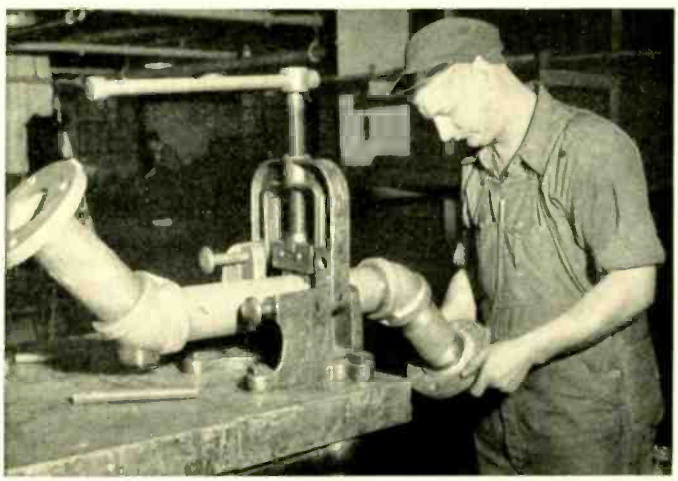
G. W. COWLEY, C. A. W. GRIERSON, R. L. TAMBLING and W. P. FRAWLEY have returned from Key West and Havana where they have been engaged in making tests on a new Key West-Havana carrier telephone system.

M. E. CAMPBELL and H. H. BENNING spent several days along the route of the Baltimore-Washington cable and at the terminals making tests on the new 0.8-mc coaxial equipment.

K. C. BLACK, H. H. BENNING and F. H. BEST made an inspection tour of the Stevens Point-Minneapolis cable to discuss the operation of the system and possible changes in future testing methods.

How the Coaxial Cable Works was explained by J. F. WENTZ to an Out-of-Hour class of New York Telephone Company employees on January 19. His talk was illustrated by lantern slides and described how various electrical processes are used and fitted together to produce the desired overall operation of a coaxial system. He also briefly discussed recent installations.

THE FEDERAL Communications Commission's monitoring station near Laurel, Maryland, was inspected recently by H. J. FISHER, O. D. ENGSTROM, H. F. WINTER and E. I. GREEN.



Teddy Olsen of the Building Shop makes up a pipe detail for a cooling system

C. Hoffmann, 1888-1942

J. W. Kelly, 1900-1942

F. L. Cox, 1867-1942

Obituaries

J. W. Kelly, a draftsman in the Patent Department, died suddenly on January 21. Mr. Kelly joined the Patent Department in 1929 and since then had been associated with the production of patent drawings covering all types of communication apparatus and systems. Before joining the Bell System he had had previous mechanical drafting experience, one year with Sackett and Wilhelm Lithographing Corporation, with the United States Army from 1919 to 1922, and then seven years with the International Motor Company.

* * * * *

Charles Hoffmann, who retired from the Systems Development Department in 1929 after twenty-two years of service in the Bell System, died on January 10. Mr. Hoffmann joined the manufacturing organization of the Western Electric Company in 1906 and for many years adjusted and assembled relays. When the manufacturing activities were transferred to Hawthorne he became a wireman in the manual circuit laboratory of the Systems Development Department. During the eight years previous to his retirement he was in charge of the wiremen in the toll circuit laboratory.

* * * * *

F. L. Cox, a former member of the Technical Staff in the Systems Development Department, died on February 5. Mr. Cox began work in the Thames Street shop of the Western Electric Company in 1895, installing power and light equipment. When the present West Street building was being constructed he assisted in wiring the first two sections—B and C. He was later permanently transferred to telephone wiring work and, at the time of his retirement in 1932, was in charge of wiring activities in the local systems testing laboratory.

* * * * *

During the months of January and February the following members of the Laboratories completed twenty years of service in the Bell System.

Apparatus Development Department

J. S. Clark — D. H. King
Miss Florence Metz — D. W. Pitkin

Systems Development Department

R. B. Bauer — W. V. K. Large
Christopher Hartley

Patent Department

Miss Elizabeth Culbert — A. J. Zerbarini

Research

Joseph Haverl

General Accounting

James Cameron

Commercial Relations

C. W. Stevens

Plant Department

R. N. Carr — Patrick Higgins

At a meeting on January 26 of the Board of Directors, A. O. Jehle was appointed General Auditor. Reporting to Mr. Jehle are G. B. Small, Auditor of Disbursements,

G. T. SELBY, Assistant General Auditor, and J. S. MCDONOUGH, Chief Auditor and Methods Supervisor. Reporting to Mr. Small are F. W. SEIBEL, payroll, T. J. MURTHA, voucher, and J. W. STONER, tabulating service; to Mr. Selby, J. SAUER, corporate accounting, H. M. GESSNER, plant accounting, and K. M. WEEKS, costs and expense; and to Mr. McDonough, W. E. MAROUSEK, audits, and C. W. F. HAHNER, methods and office standards.

F. H. BEST visited Minneapolis and Stevens Point in connection with tests of the coaxial system.

R. G. KOONTZ was in Baltimore to discuss with engineers of The Chesapeake and Potomac Telephone Company changes in the number-group circuits for the Saratoga crossbar office.

C. E. BOMAN visited the Harvey Hubbell Company and the General Electric Company at Bridgeport, Conn., to discuss special cables.

H. W. HEIMBACH visited Baltimore in connection with problems on the a-c key-pulsing equipment. Mr. Heimbach also went to Hawthorne in connection with the manufacture of sender-test frames for the No. 4 toll crossbar.

T. J. GRIESER and A. C. GILMORE, also at Hawthorne, discussed private-branch exchange equipment.

THE VITAL TASK OF COMMUNICATION

The American battlefront stretches around the world. To succeed in this kind of war a nation must have fast and accurate communications. The science of sound on which modern communications is built is at the very heart of the world-wide struggle.

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The Telephone Hour, February 2, 1942.

High-Precision Frequency Comparisons

By L. A. MEACHAM
Circuit Research

IN THE development of frequency sources of high precision and stability, used in many branches of electrical communication, it is necessary to provide means of measuring the performance of these sources. The measurements, to be significant, must detect irregularities smaller than the allowable variations of the currents themselves: if a 100-kc oscillator, for example, is intended to be stable within one thousandth of a cycle per second, the test circuit should be able to detect a variation in the order of one ten-thousandth cycle per second.

One means for checking the stability of high-frequency oscillators has already been described in the RECORD:* the "spark chronograph." This equipment does not measure instantaneous changes, but records the average variation over a considerable period of time. The number of cycles of current generated by the oscillator is counted by a synchronous motor, while the elapsed time is indicated by signals from the Naval Observatory at Arlington. The score of cycles versus time is chalked up by the chronograph at the end of each hour. Observations carried on over a week or more provide a satisfactory measure of the tested oscillator's average performance.

When the measurement must be made within a short period this direct method fails, because elapsed time cannot be determined with sufficient accuracy; but since deviations rather than absolute values are of interest, it is possible to substitute comparisons between the frequencies of two or more similar but independent oscillators. If these are constant with respect to each other within observed limits and are truly independent, probability assures the constancy of the individual frequencies within the same or closer limits. That excellent precision is obtainable by this method is shown by experience with equipment built in the Laboratories to

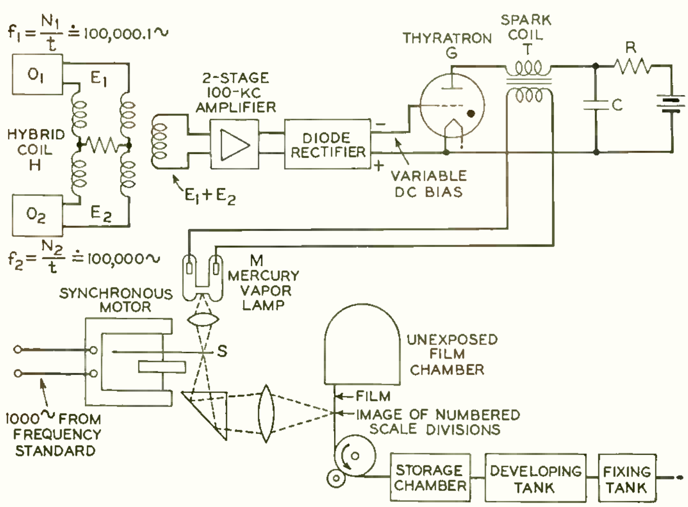

Fig. 1—Circuit for measuring short-time stabilities of standard-frequency oscillators

*October, 1939, page 54.

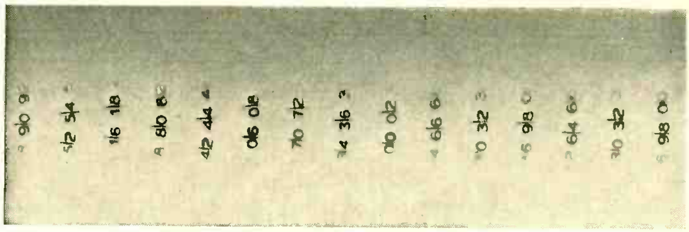

Fig. 3—Section of a typical film recording from the timing disc. Differences between successive readings give the beat periods in milliseconds

check the performance of the bridge-stabilized oscillators used in the Bell System frequency standard. The oscillators were designed to be stable within one ten-thousandth cycle per second, and the testing circuit had therefore to detect a variation in the order of one hundred-thousandth cycle. Furthermore, since the changes to be examined might be momentary, it was essential that the measurements represent nearly instantaneous frequency values and be obtained at very brief intervals.

Figure 1 is a simplified schematic of the testing circuit. The two 100-kc oscillators o_1 and o_2 are adjusted to differ in frequency by about one-tenth cycle per second. Their outputs are added together in a hybrid coil and the sum amplified and rectified to

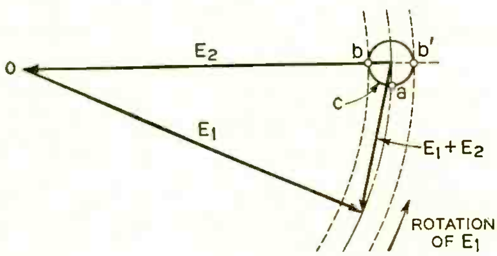

Fig. 2—Vector diagram of voltages at input of measuring circuit

fire a thyratron tube once each beat cycle, in turn discharging condenser c through a spark coil. High voltage generated by the coil causes a brief flash of light in the neck of a mercury vapor lamp. To record the time between flashes a circular scale marked in milliseconds is rotated by a 1000-cycle motor synchronized with current from the frequency standard. Each discharge illuminates the scale and records the time on a slowly moving film.

In this way the time elapsed during a single ten-second beat cycle is recorded to the nearest thousandth of a second, and any irregularity in the beat frequency amounting to more than one part in ten thousand becomes apparent. As the frequency of the beat pulses is only one-millionth $\left(\frac{1}{10 \times 100{,}000}\right)$ of the frequency of either 100-kc oscillator, the precision of the comparison between the pair of oscillators is approximately one part in ten thousand million (10^{10}). To take a specific example, suppose that one of the oscillators, o_1, has a frequency of precisely 100,000 cycles per second and the other, o_2, a frequency of 100,000.1 cycles. This difference of 0.1 cycle per second, or one part in a million, produces a beat once in ten seconds. If the frequency of o_2 changes to 100,000.1001, the beat period will be shortened by .01 second, or ten divisions on the scale. Thus an irregularity so small as to be undetectable by any rapid direct method produces a very noticeable record in the measuring device.

The principal problem in designing the measuring equipment is to insure that the thyratron will be fired at the same point in each beat cycle; other-

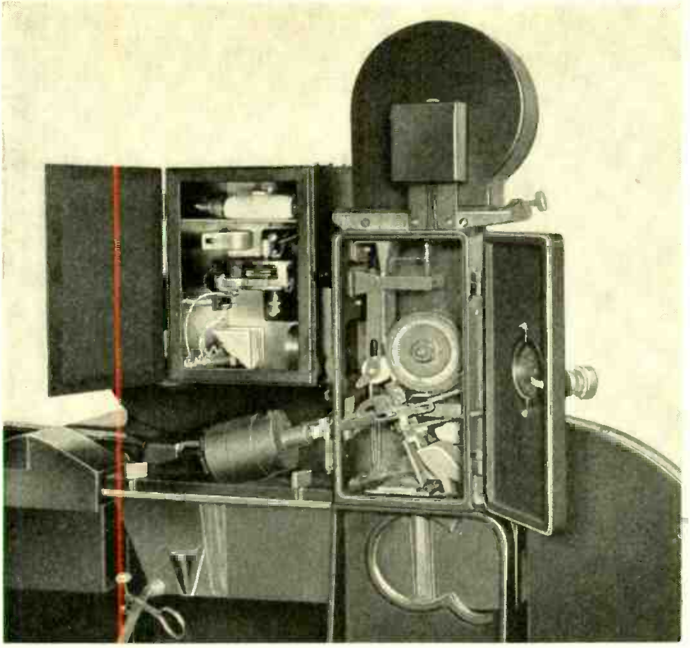

Fig. 4—Equipment for precision frequency comparisons

wise a recorded change may be due to irregularity in the testing device rather than in the oscillator. The two oscillator outputs must be so compared that some condition for firing is satisfied abruptly and at a definite relative phase angle of the cycle. How this is done can most easily be explained by referring to the vector diagram shown in Figure 2.

In this diagram E_1 represents the output voltage of one of the oscillators rotating in phase at the beat frequency with respect to the other, E_2. The sum of the two voltages, added together in the hybrid coil, is represented by the vector $E_1 + E_2$, which changes constantly in length throughout the beat cycle. This vector is amplified and rectified to provide negative bias on the thyratron grid. When the bias falls below a certain value determined by the design of the tube and represented by the radius of circle c, the tube fires. In other words, a record is made whenever the end of vector E_1 dips inside c.

If the point of entry is at *a*, as when the two output voltages are precisely equal, the firing comes earlier than if they are slightly different and the end of E_1 barely grazes the circle at *b* or *b'*. The possible error thus introduced is measured approximately by the ratio of the radius of c to the circumference of the circle swept by the end of E_1. This error is made sufficiently small by amplifying the vector $E_1 + E_2$ before rectification, and thus increasing the sensitivity, or effectively reducing the radius c. When the voltages are thus critically compared their amplitudes must be almost identical or no record is ob-

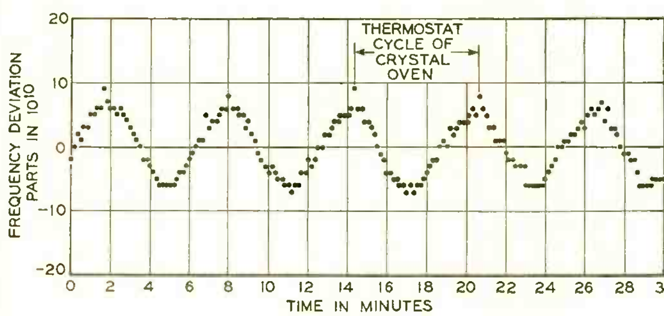

Fig. 5—Short-time frequency comparisons between independent bridge oscillators in normal operation

tained; but if the thyratron fires at all, it must do so at a time known within exact limits. In the practical measurement of the bridge oscillators enough gain was used so that oscillator outputs were about 65 db larger than the critical value of their sum required to fire the tube and thus had to be alike in amplitude within about 0.05 per cent.

Other problems encountered in designing the measuring equipment are overloading in the amplifier, variations in its gain, and changes in the firing potential of the gas tube. The amplifier does overload severely during most of each beat cycle, but not during the critical period when E_1+E_2 becomes small. The other items cause first-order changes in sensitivity, but only very small errors in the measurements themselves. Harmonics of 100 kc, if present in the mixing circuit and amplified, might prevent the desired complete cancellation of the oscillator outputs. This has been avoided by tuning the amplifier to 100 kc at several interstage points. The efficacy of the tuning has been checked by noting that when the outputs are in optimum level adjustment, the minimum value of E_1+E_2 is well within the critical firing value.

Possible tendency for the two oscillators to lock into step, or otherwise mutually interfere, has been found negligible, for several reasons. A buffer amplifier is employed in the output of each oscillator; the frequencies being compared differ by a large amount in comparison to their individual fluctuations; they are combined in a balanced hybrid coil which affords perhaps 20 db of attenuation between them; and all the consecutive records are made at the same point in the beat cycle, accurately repeating any cyclic advance or retardation of phase, which thus subtracts out when the beat periods are calculated.

Figure 4 shows the motor and the optical system attached to the frame of a Bell Laboratories rapid-record oscillograph and utilizing its film drive and developing apparatus. Light from the mercury vapor lamp is focused on the film within the oscillograph turret. The film moves just fast enough to separate successive records. Figure 3 shows a typical film recording from the timing disc. Differences between successive readings, augmented by an initial stopwatch check of the ten-second intervals between flashes, give the beat periods in milliseconds.

Measurements of a pair of the oscillators now used in the Bell System frequency standard are given in Figure 5 for a typical half-hour run. The plotted points represent frequency differences between the oscillators. For clarity the average of the whole set of measurements has been taken arbitrarily as the zero of deviations. The measurements show a sinusoidal variation with an amplitude of about six parts in ten billion. The obvious guess that this sine wave is associated with the intermittent heating of the crystal temperature control ovens has been confirmed by correlation of the periods involved. The small scattering of individual readings, in the order of only plus or minus one part in ten billion, is due to the fluctuations in all other operating conditions, such as the supply voltages, and to remaining inaccuracies in the measuring equipment.

Grounding of High-Gain High-Frequency Amplifiers

By T. F. GLEICHMANN
Transmission Development

STABILIZED feedback has been of incalculable advantage in the design of amplifiers, since it gives almost complete control of variations in gain, and makes possible drastic reductions in the distortion and noise produced in the amplifiers themselves. It is secured by providing a carefully designed feedback path between the output and input of an amplifier stage or of an entire amplifier. While feedback may thus be a blessing to the amplifier designer, it is so only because it takes place over a properly designed path. If, however, the path over which the feedback occurs is a fortuitous one, singing or objectionable crosstalk between different amplifiers may take place unless the amount of feedback is very small.

In almost any amplifier there are couplings of one sort or another between circuit elements, and these may form paths over which the feedback is not controlled. With amplifiers of small or medium gain, however, operating at moderate frequencies, the amount of feedback over such paths may generally be kept small enough to have little effect on the operation of the amplifier. With high-gain amplifiers operating at very high frequencies, however, the situation is more difficult to control because both high gain and high frequency tend to increase the amount of fortuitous feedback that is present in the circuit.

A common cause of these feedback couplings is mutual impedances in the ground path of several stages; that is, currents in the ground path of one stage flow through impedances that are also part of the ground path of another stage. Consider, for example, an amplifier of which some of the elements of the first and last stages might be as represented in the upper diagram of Figure 1. Ground connections are commonly made by attaching the lead to the metal panel on

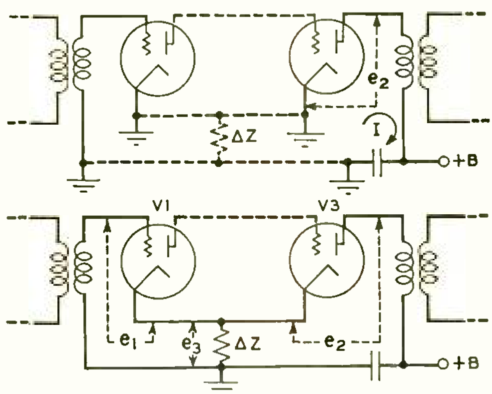

Fig. 1—In a typical amplifier, currents from plate to cathode flow in the panel for all stages, and thus have the common impedance ΔZ. Such an arrangement is thus equivalent electrically to the lower diagram

which the apparatus is mounted, and in Figure 1 it will be noticed that both of the cathodes are so grounded as are also the input and output circuits. The return path between plate and cathode for the stages thus includes the common panel which has an impedance that may be called Δz. In view of this situation the circuit may be represented electrically as shown in the lower diagram. An analysis of this diagram shows, for example, that current flowing in the output circuit due to e_2 must return to the cathode through Δz. This results in a voltage drop e_3 across Δz, which is applied directly to the input as a potential e_1.

In the situation represented by Figure 1, the feedback coupling is through a common impedance, but other types are possible. Even when the ground leads are run so that there is no physical impedance common to the input and output stages, there may be coupling due to mutual inductance between the ground leads. This is indicated in Figure 2. The effect of this mutual inductance is the same as that of the mutual impedance in Figure 1.

Coupling may also occur through capacitance as shown in Figure 3. The shield between the windings of the output transformer may be grounded, and thus any current flowing in it may pass to the input through any such mutual impedances as indicated in Figures 1 and 2. Output current may enter the shield through the capacitance between windings and shield, and will then affect the input as in the previous examples. The electrical equivalent of this circuit is shown in the lower diagram of Figure 3. Current flowing from the plate of the output tube through the capacitance to the shield passes through the mutual impedance Δz, causing a voltage drop e_3 and a voltage e_1 across the input to the first tube. Although the capacitance between the shield and winding of the

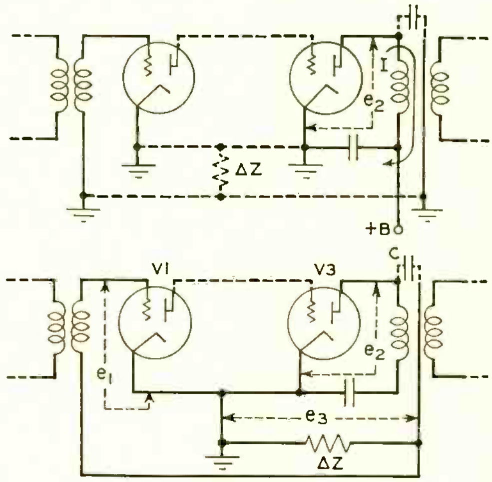

Fig. 3—Ground current may also flow through the capacitance to the shield of the output transformer, and thence through any existing mutual couplings. The electrical equivalent of this circuit is shown in the lower diagram

output transformer was picked as a specific example, the capacitance of any element to the panel may be part of the coupling path.

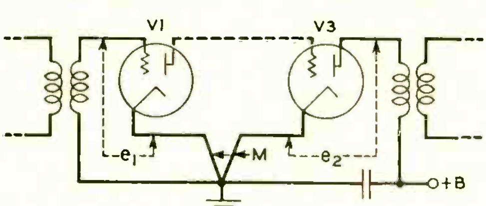

Fig. 2—Electrical equivalent of a circuit similar to that of Figure 1 but with mutual inductance between ground leads of input and output stages

With a high-gain amplifier, the value of the mutual impedance Δz must be kept exceedingly small. Consider, for example, a line amplifier for the type-K carrier system, and assume that the singing margin by way of the fortuitous feedback path must be at least 20 db if the effect of the feedback is not to be objectionable. At 60 kc, the voltage amplification from the input to the output, exclusive of the input and output transformers, is 105 db, and thus if the net loss around this feedback path is to be 20 db, the loss from the output back to input over the feedback path must be 125 db. The voltage across Δz will be in the same proportion to the output voltage as the impedance Δz is to the output impedance. In this amplifier, the output impedance is 3500 ohms, and thus to keep the feedback to the desired value, the ratio of Δz to 3500 must be that represented by 125 db, the desired loss in the feedback path. 125 db, however, corresponds to a ratio of 1 to 1,778,000, and thus Δz must not be greater than 3500 ÷ 1,778,000, which is .002 ohm. This is an extremely small impedance. At 60 kc a piece of No. 18 copper wire 0.4 inch long has about this impedance, and two parallel straight wires, one inch long and 0.5 inch apart, also have the same impedance through their mutual inductance. For the situation shown in Figure 3, the value of Δz may be somewhat larger, because of the small capacitance between winding and shield, but in all cases the mutual impedance must be exceedingly small.

The coupling paths indicated in Figures 1 to 3 become increasingly important as the frequency is increased. The impedance of the panel, since it is mainly inductive, increases with frequency and thus Δz becomes greater, and coupling by paths similar to Figures 1 and 2 is made worse. In the situation represented by Figure 3, a double effect takes place as the frequency is raised, since the impedance of the coupling capacitance is reduced while Δz is increased. Hence, while it may be relatively easy to hold a particular gain at one frequency, it may be difficult to hold the same gain at a higher frequency.

Once the nature of this feedback situation is realized, the course the correction should take is fairly obvious. The ground paths for each stage should all be closed on themselves so that there is no common impedance for the currents of different stages. This method is shown schematically for one of the type-K carrier amplifiers in Figure 4. It will be noticed here, for example, that the plate and cathode circuits for each stage are connected to the same point so that the Δz of Figure 1 is eliminated. Also the shield of the output transformer is so connected that there is no common impedance for the

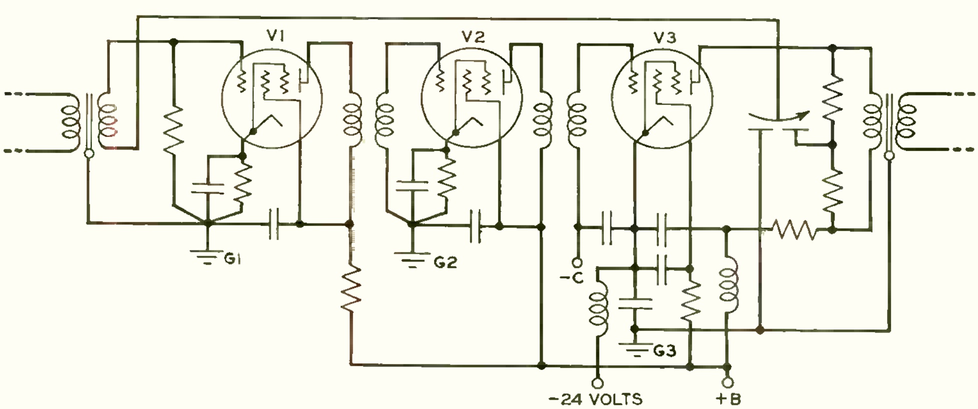

Fig. 4—Simplified schematic of line amplifier for the K carrier system showing system of grounding adopted to avoid mutual impedances in ground paths

shield current and that of the input circuit. Furthermore, all ground connections are made as short as possible and kept away from those of other stages. For this reason the ground leads should never be run in "forms" with other leads but carried directly to the ground points.

The impedance Δz of Figures 1 to 3 does not necessarily have to be on the same panel, but may be a common impedance between two panels. Under these conditions v1 and v3 would be on separate panels, and the voltages shown would give rise to objectionable crosstalk between amplifiers.

The method of grounding shown in Figure 4, which keeps the high-frequency currents out of the panel, also aids in reducing the crosstalk between amplifiers when several are mounted on the same relay rack. If this method is not used, part of the signal current flowing in one panel may find its way into the panel of another amplifier on the same rack. This current flowing through the panel impedance sets up voltages within the second panel, and results in a voltage appearing at the output of the second amplifier due to a signal on the input of the first amplifier. One way in which this has been eliminated in the past is by breaking up the path by insulating the panels from the racks, thus keeping the current from one amplifier from entering the other amplifier. By following the grounding technique outlined, amplifiers with gains of 70 db or more at 60 kc may be mounted directly on a rack one above the other, the separation between the outputs being 100 db or more.

This grounding technique has proved valuable in meeting the singing margin and crosstalk requirements for the type-J and K repeaters. In the design of a ten-megacycle amplifier for a high-frequency oscilloscope,* this technique resulted in sufficient separation between the outputs of two 60-db amplifiers to permit the amplifiers to be mounted on the same panel. The separation was at least 50 db at ten megacycles.

*Record, *December*, 1941, *page* 95.

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*Articles by H. M. Pruden and A. C. Peterson, Jr., were made up as part of this issue of the RECORD. Although they dealt with peacetime telephonic developments, in view of the possibility that they might disclose technical material useful to the enemy, they were withdrawn as the magazine went to press.

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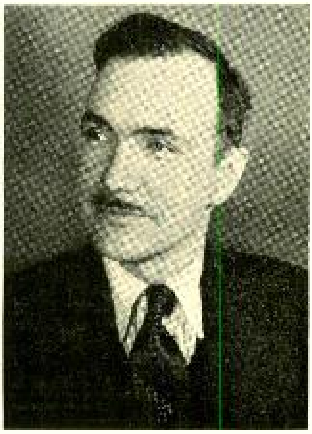

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Defense Savings Bonds

To assist its members in the purchase of U. S. Bonds by deductions from salaries, the Laboratories in recent years has contributed services by its Accounting and Financial Departments. Today many are buying Defense Savings Bonds under its payroll allotment plan; and a recently formed committee is undertaking an intensive campaign for even greater participation