BELL LABORATORIES RECORD

ORCHESTRAL MUSIC IN AUDITORY PERSPECTIVE

—

RADIO TELEPHONE EQUIPMENT FOR TRANSPORT AIRPLANES

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In this Issue

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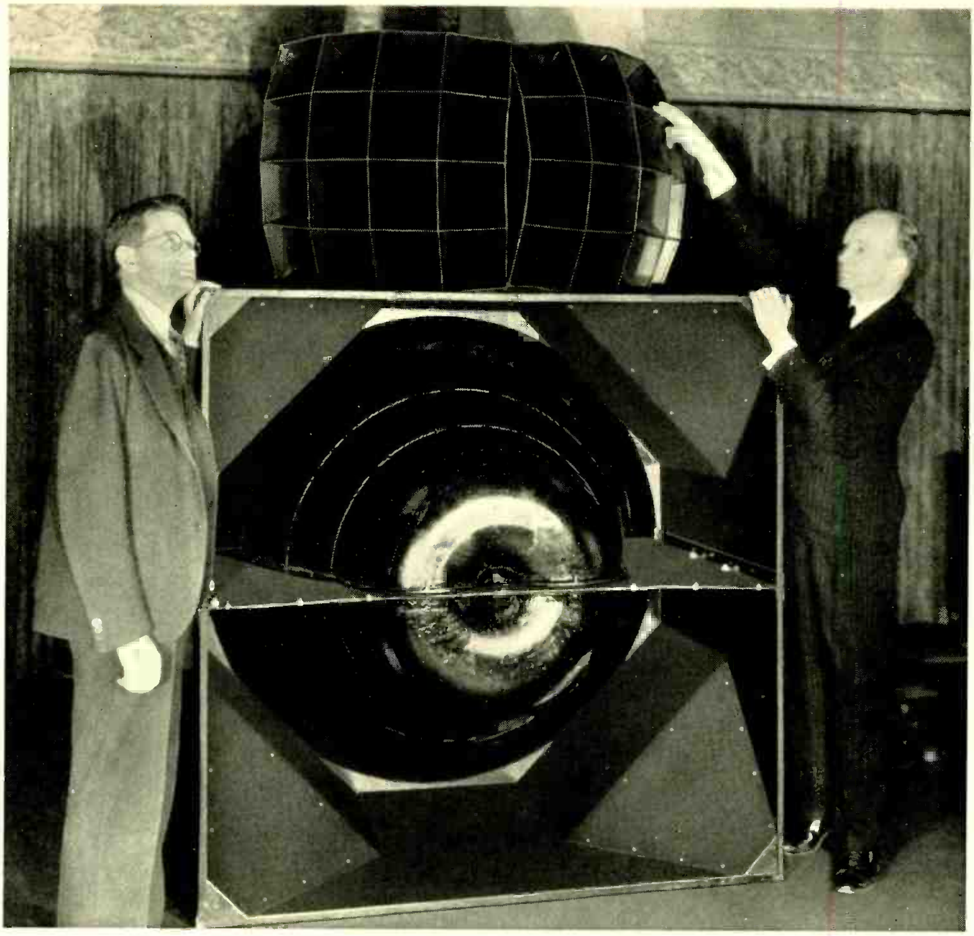


The Reproduction of Orchestral Music in Auditory Perspective

IN this electrical era it does not seem very remarkable that music, even from a large symphony orchestra, should be picked up by microphones, transmitted over telephone wires, and reproduced at a distant point. Most of us probably hear it accomplished every day by means of the radio, and radio transmission and reproduction would, in general, be called good. Between good reproduction and perfect, however, there is a very wide gap, and the difficulties of crossing it are probably not realized by those not technically familiar with the subject. Perfect reproduction, of a symphony concert for example, would make it impossible for one listening with his eyes blindfolded to know that the actual orchestra was not on a stage before him. Not only would every tone and over-tone be present in its correct relative volume, but there would be a depth and color which is not ordinarily obtained when electrical apparatus intervenes between the orchestra and the audience.

Three classes of requirements must be met if the reproduced sound is to be indistinguishable from the original. Two of them, that both the complete frequency and complete volume ranges be transmitted, have been generally recognized for some time. The third, that the sounds must be reproduced with the correct auditory perspective, has been fully appreciated only by those most closely associated with the science of sound reproduction.

Sounds in general are composed of a group of tones and over-tones ranging from the deep bass of the lowest organ notes, or those of a bass drum, to the shrillest tones the ear can hear. Each note of a musical instrument has a fundamental tone and a group of harmonics. The fundamental tone sets the pitch, and the harmonics give the note its quality. It is the harmonics that make it possible to distinguish a note on a violin from one on a trumpet or from any other of the same pitch. It is in the harmonics that reside the richness of music and the wealth of sensuous appeal. These tones and over-tones are known and recognized by their frequency, or vibratory rate; and the range of frequencies to which the ear responds runs from about 16 cycles per second to 16,000, or even 20,000 cycles for some ears. The sensitivity of the ear falls off rapidly at the higher frequencies, however, so that the effect of frequencies above 15,000 cycles is negligible for the most part. The highest note on the piano has a fundamental frequency of only about 4,000 cycles, and few of the musical instruments exceed this pitch, but the accompanying harmonics or over-tones, which are of still higher frequencies, are very necessary to the proper quality and richness of the notes.

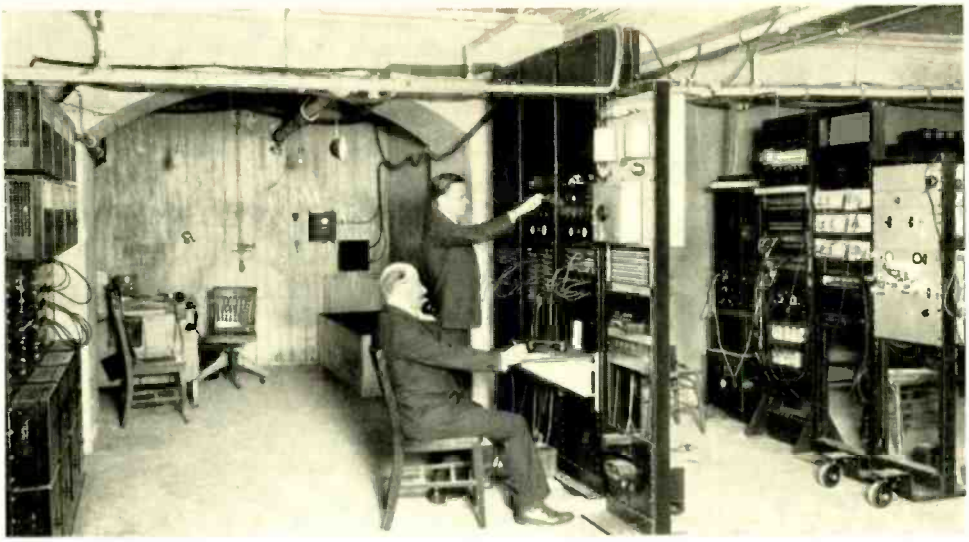
Of no less importance, if the full aesthetic effect of music is to be obtained, is the range in volume. The ear has a recognizable range of volume as it has of frequency. This extends from sounds so low that the ear cannot hear them, to sounds so great that the sensation is one of pain rather than of hearing. For convenience in scientific study, the power of sounds is graded in units known as decibels (abbreviated db). The threshold of hearing is taken as a reference base, and the ordinary audible range runs from the volume of sound one would hear in a quiet garden, or that of an average whisper at a distance of four feet, which are at a level of 20 db, to that of a pneumatic riveter, at a level of 100 db—a total range of about 80 db. The range of a large symphony orchestra is about 70 db, so if the music of such an orchestra is to be faithfully transmitted electrically, a volume range of the order of 70 db must be transmitted: a range of power of ten million to one.

The third requirement becomes of particular importance when the sound to be transmitted and reproduced is that from a large and relatively widely spaced group of instruments, such as a complete symphony orchestra. When one sits in an auditorium and listens to a symphony concert he experiences something that is over and above the effect produced by the actual frequency and volume range given out by the orchestra. This additional appeal is difficult to describe, and almost impossible to measure. It is partly due to a spreading of the sound in all directions so that it fills the entire volume of the auditorium and thus reaches one's ears by various paths. It is partly due to other factors; but whatever its cause it results in a richness and texture of tone that no ordinary electrical reproduction can provide. For lack of a better term, the effect may be called auditory perspective. Without it the music would be one dimensional and not expanded into its true spatial relationship. The difference may be compared to that between the appearance of a photograph of a scene and the same scene when viewed through a stereoscope.

How to obtain this auditory perspective in music transmitted and reproduced electrically was discovered by the scientists of Bell Telephone Laboratories as a result of their fundamental investigations in acoustics and telephonic transmission. During the course of those investigations they had developed telephonic systems of high quality, but for their further researches they needed opportunity to utilize music in its most perfect forms. Now it happened that Dr. Leopold Stokowski, Director of the Philadelphia Orchestra, was interested in the possibilities of electrical systems for the production of exceptional orchestral effects. Through his voluntary cooperation, therefore, the Laboratories' scientists were able to make quantitative physical studies of music as rendered by his orchestra, and so to perfect their designs; and with the completion of the new equipment some of the possibilities which Dr. Stokowski had hoped for became practicable. An extended series of tests was then carried on in Philadelphia in which the Laboratories' scientists were generously assisted by Dr. Stokowski. As a result of these studies, it was found that by employing two microphones, one properly located on each side of the stage, and by transmitting over two separate circuits to two of the newly developed loud speakers, similarly placed, the effect of the actual presence of the orchestra was successfully obtained.

Even with the discovery of a comparatively simple means of obtaining true auditory perspective, the problem was not completely solved. Never before had either the complete frequency, or the complete volume range, of a symphony orchestra been commercially transmitted and reproduced. No complete chain of apparatus, from microphone to loud speaker, was available that would faithfully transmit the entire range of frequency and volume. Microphones perhaps offered the fewest difficulties. Bell Laboratories had already designed sensitive microphones that would transmit practically the entire range required, and only minor modifications were needed to make them entirely suitable.

This was not true of the amplifiers. There had to be developed amplifiers which would faithfully transmit all frequencies from 35 to 16,000 cycles at levels from the barely audible pianissimo effects to the resounding orchestral crashes of ten million times greater power; and all the pieces of apparatus had to be so designed that even during intervals of complete silence not the slightest noise would be introduced to suggest the presence of electrical apparatus. No underlying hum or noise, such as is commonly present in radio or other systems of reproduction, could be tolerated with the new apparatus. In the intervals of silence there must be real silence: a dead auditory void in which the fall of the lightest pin could be heard. This has actually been accomplished to a degree heretofore unknown. Probably the most quiet electrical reproduction up to the present is that obtained with high-grade sound picture apparatus; but such apparatus at its most quiet moments gives off 300



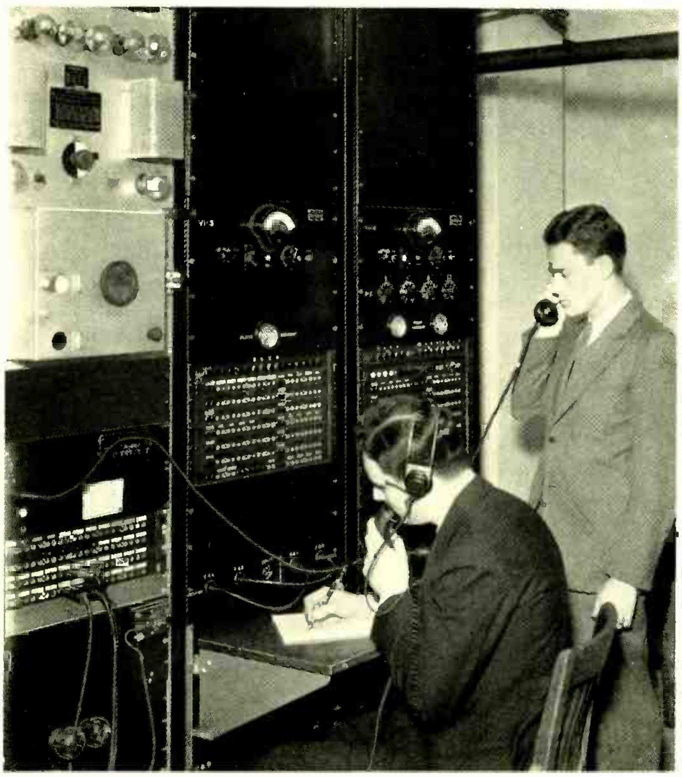
Control room in the basement of the Academy of Music in Philadelphia. W. A. Munson of the Laboratories is standing at the voltage amplifiers

times more sound than the new apparatus when the musicians are silent.

Of even greater difficulty possibly was the design of suitable loud speakers. It is not practicable to obtain the entire frequency range with a single unit, and so two types of loud speakers are used. One, somewhat resembling the horns used for sound pictures, is employed for the frequencies from 35 to 300 cycles; and another type, for the range from 300 to 16,000 cycles. These loud speakers are different from anything previously produced commercially. Never before have these elements fulfilled such difficult requirements of frequency range and volume. The best sound picture systems record and reproduce approximately half the range of frequencies handled by the new loud speakers, and the best radio systems even less. In volume range the comparison is equally remarkable. Although sound picture systems under the most favorable conditions may provide a volume range of 40 or 45 db, radio systems rarely exceed 30, while the range provided by the new apparatus is well above 80. Whereas the power range of radio is of the order of 1000 to 1, the new equipment is capable of yielding a range of 100,000,000 to 1.

The new loud speakers and their associated equipment of amplifiers and microphones are, therefore, fully capable of handling the entire volume range of a symphony orchestra. When one speaks of range of loudness which can be handled by an electrical system for reproduction, one is concerned with the differences between the loudest and faintest passages of the music which it can reproduce. There is in addition the problem of handling the peaks of maximum loudness. These peaks in the case of music from a symphony orchestra are beyond the possibilities of the ordinary loud speaker to reproduce without distortions which seriously affect the musical sonority. The low frequency sounds make the largest contribution to the peaks of sound power which must be handled to meet these conditions. The diaphragm of the low frequency element in the new loud speaker has been made nearly seven times larger than that of the elements used ordinarily for sound picture reproduction. By these diaphragms a large column of air is set into motion.

The ordinary loud speaker also becomes directional in its characteristics at the higher frequencies. Low frequency sounds spread in all directions from the mouth of the horn, but the higher frequencies tend to concentrate into a beam projected directly ahead of the horn; and the width of the beam becomes narrower and narrower as the frequency increases. Because of this fact, the audience, in a large hall equipped with the ordinary loud speakers, never hear quite the proper blending of frequencies. Those directly in front of the horn receive too great a proportion of the higher frequencies, while those on the sides receive too much of the low frequencies. To avoid this effect, the horn of each high-frequency element is divided into 16 diverging rectangular sections which spread the sound over an arc of 60 degrees vertically and one of 60 degrees horizontally. Two of these units placed side by side thus spread the sound over a horizontal angle of 120 degrees—a far wider coverage than has been obtained before and one which distributes the sound throughout the auditorium with a faithful blending of the frequencies.



R. J. Tillman of A. T. & T. (left), and A. R. Soffel of the Laboratories at the voltage amplifiers in Constitution Hall, Washington

Besides providing for the full volume range of the orchestra, the amplifiers have an additional amplification of at least 10 db, so that, if desired, the volume of loud passages may be made ten times as great as the actual output of the orchestra. Technically described, the maximum sound power of a symphony orchestra integrated over an interval of two-tenths of a second is less than 20 watts, whereas that possible from the loud speakers of the new apparatus is more than 200 watts. This additional gain allows effects to be obtained which have been impossible before. Besides the effects of range and quality of tone, the total aesthetic appeal of an orchestra is due in no small degree to the range in volume. The number of musicians one can place on a stage is limited. To put ten times as many as contained in a modern symphony orchestra is impossible in any existing hall. The control of volume given by the new apparatus enables the director to secure at will the equivalent of an orchestra of nearly a thousand musicians.

The advantage of this control of volume does not end here, however. Its presence makes it possible to reproduce operatic music, where a soloist is accompanied by an orchestra, without allowing the voice of the singer to be drowned out by the louder passages. For this purpose a third channel, including its separate microphone, transmission line, and loud speaker, has been provided in the new system primarily for the singer. The volume of output of this channel is controllable independently of the other two. In this way the loudness of the voice may always be kept just above that of the orchestra and the desired musical effect be obtained. There thus reside in the new apparatus possibilities heretofore unattainable; and telephonic research has laid a foundation for what may be one of the greatest advances in musical aesthetics of the present scientific era.

The first public demonstration of the new apparatus was given in Washington on the evening of April 27 under the auspices of the National Academy of Sciences. At that time Dr. Stokowski, Director of the Philadelphia Orchestra, manipulated the controls from a box in the rear of Constitution Hall, while the Philadelphia Orchestra, led by Associate Conductor Alexander Smallens, played in the Academy of Music at Philadelphia. Between Philadelphia and Washington, the music was transmitted over telephone cable circuits. The program consisted of the Toccata and Fugue in D Minor, of Bach; Beethoven's Symphony No. 5 in C Minor; L'après-midi d'un Faune, of Debussy; and the Finale of Götterdämmerung. A visual accompaniment was provided for the music by Electrical Research Products, Incorporated. Its stage direction—through the courtesy of the Yale School of Drama—was by S. R. McCandless, and the designs were by Eugene Savage and George Davidson.

During the intermission Dr. W. W. Campbell, President of the National Academy of Sciences, introduced Dr. Harvey Fletcher, Director of Acoustical Research at Bell Telephone Laboratories. With the assistance of the orchestra in Philadelphia, Dr. Fletcher then performed several experiments to demonstrate the important characteristics of the new apparatus. On the stage of the Academy of Music in Philadelphia, where the pickup microphones were installed, a workman busily constructing a box with hammer and saw was receiving suggestions and comments from a fellow workman in the right wing. All the speech and accompanying sounds were transmitted over cable circuits to the loud speakers on the stage of Constitution Hall in Washington. So realistic was the effect that to the audience the act seemed to be taking place on the stage before them. Not only were the sounds of sawing, hammering and talking faithfully reproduced, but the correct auditory perspective enabled the listeners to place each sound in its proper position, and to follow the movements of the actors by their footsteps and voices.

For another demonstration, the audience heard a soprano sing "Coming Through the Rye" as she walked back and forth through an imaginary rye field on the stage in Philadelphia. Here again her voice was reproduced in Washington with such exact auditory perspective that the singer appeared to be strolling on the stage of Constitution Hall.

An experiment which demonstrated both the complete fidelity of reproduction and the effect of auditory perspective was performed by two trumpet players. One, in Philadelphia at the left of the stage of the Academy of Music, and the other in Washington at the right of the stage of Constitution Hall but invisible to the audience, alternately played a few phrases of the same selection. To those in the audience there seemed to be a trumpet player at each side of the stage before them. It was not until after the stage was lighted that they realized that only one of the trumpet players was there in person. The music of the other was transmitted from Philadelphia with such perfect fidelity and reproduced in such true perspective that it was impossible to tell that one of the players was absent.

The auditory perspective effect is not restricted to placing sounds in their correct positions across the stage, but is three dimensional. This was shown by having several sources of sound moved around the stage in Philadelphia, not only back and forth but high up in the center of the stage as well. The movement of each sound was faithfully reproduced by the loud speakers in Washington even when the sounds were carried high above the level of the stage floor.

To show the volume range possible with the new equipment, the orchestra played a selection at a constant level of loudness while the output of the loud speakers was varied from a level so low that the instruments could scarcely be heard, up to a loudness almost great enough to be painful. Throughout the whole range, the reproduction was faithful in all respects except the level of loudness; there was no distortion or noise to mar the perfection of the reproduction, and the wide range in volume was vividly impressed on the audience.

The effect of limiting the range in pitch, or frequency, was illustrated by employing electric filters to cut out one octave at a time—first from the upper end of the range and then from the lower. The new apparatus reproduces faithfully about 9 octaves or from 35 to 16,000 cycles, compared to about six for ordinary radio reproduction. By this demonstration the audience had the opportunity of judging the importance of the complete range to the full aesthetic appeal of music, and of comparing it with the more limited ranges ordinarily heard.

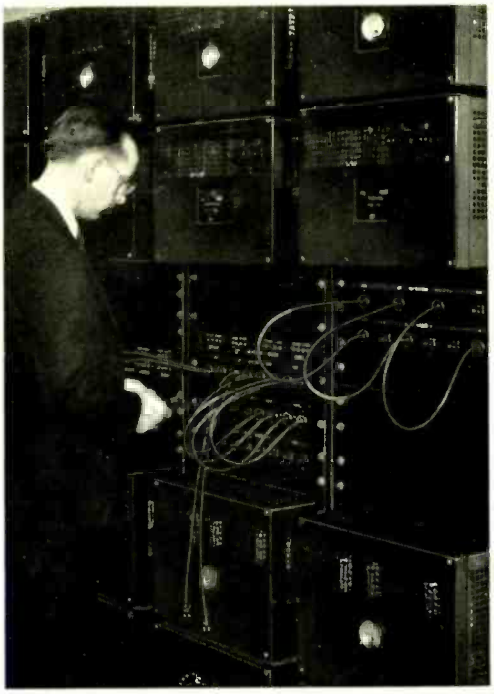
The technical features of these new developments, which were carried on as part of the research program of the American Telephone and Telegraph Company, were disclosed for the first time by Dr. F. B. Jewett, Vice President of the American Telephone and Telegraph Company in charge of development and research, at a meeting of the National Academy of Sciences on Tuesday afternoon of April 25. In discussing the future of the new system, Dr. Jewett said:

"As to the future of the accomplishment shown here today, it is difficult to make any definite prediction. What we have done is to produce pickup microphones, amplifiers, electrical filters, transmission lines and loud-speaking reproducers so perfect that the entire frequency and volume range of the most exacting orchestral and vocal music can be reproduced at a distance without impairment of quality. We have also worked out the arrangements by which substantially perfect auditory perspective is possible. This latter is an essential part of the problem if realistic illusion as to the physical arrangement of the component parts of an orchestra is desired.

"We can place at the disposal of the musical director instrumentalities which will enable him to produce at a distant point, or at many distant points simultaneously, a completely faithful replica of the tonal effects produced locally in the auditorium on the stage of which the orchestra is performing. Likewise, portions of this same equipment place at his disposal the means of very greatly extending the range of orchestral reproduction and of making possible artistic effects hitherto unattainable.

"With these instrumentalities available, the questions of the manner and extent of their use are primarily questions for the musician and those interested in music rather than for the physicist and the engineer. Our job has been to produce a set of tools. The musicians and musical directors, and back of them the musical composers, must determine just how these tools can best be used and what they can best produce. By its very nature the ensemble of what we have created is primarily of value for musical production or reproduction in halls, theatres or auditoriums. In a word, its field of applicability is where a large number of people might congregate for the common enjoyment of music of distinction. In its present form it is not directly applicable to the limited environment of the home.

"These new tools offer not only an enlarged field of possibility to the musician and the composer for the production of auditory effects, but likewise a great broadening of the audience which derives pleasure from such effects. Many people, especially in our smaller cities, are now deprived of the ability to hear good orchestral music by the factors of cost and distance, and the element of time in going to the cities where orchestral music is normally produced. What we as physicists and engineers have done is to provide a mechanism for obviating these factors. Whether the results justify our hopes is for others to say."



D. T. Bell of the Laboratories at the power amplifier panels in Washington

Reprint of a souvenir booklet prepared for a demonstration before the National Academy of Sciences on April Twenty-seventh, 1933, at Washington, D. C.

New Radio Telephone Equipment for Transport Airplanes

By D. K. MARTIN
Radio Development Department

THE air transport industry, almost alone in the past few years of generally reduced commercial activity, has steadily increased its volume of business. Graphs showing miles flown and passengers carried both present a striking contrast to a plot of the general index of industrial production. Along with this rapid growth in volume of transport business has gone an increase in cruising speed, and even greater speeds are an immediate prospect. Radio aids, by making flying safer and times of departure and arrival more certain, have contributed in no small degree to the general success of the industry. Such aids are, in general, of two types: the beacon signals and weather reports of the Department of Commerce, and the radio telephone systems operated by the transport companies themselves. The growth of both of these types of service has paralleled that of the air transport industry itself.

In 1929 the Western Electric Company brought out their complete line of airplane radio equipment, which has already been described in the RECORD*. Although the requirements for airplane radio-telephone service were not clearly defined in detail at that time, Bell Laboratories' engineers were intimately acquainted with the needs in their broader aspects, and the apparatus they developed proved highly satisfactory.

During the three years 1929-1932,

*RECORD, *October*, 1930, *pp.* 59-79.

however, the transport communication picture has changed considerably with the large increase in the number of planes equipped for radio telephony. The frequency band available for airplane telephony is strictly limited, and the increased demand for channels has made it necessary to squeeze the assignments closer together. With the old equipment this has resulted in interference between channels operated by different transport organizations. An imperative need has thus arisen for receivers of greater selectivity.

Another feature which it seemed highly desirable to incorporate in the new apparatus is the ability to change the frequency easily. Radio transmission conditions at night are different from those during the day so that two frequencies are universally employed: one in the vicinity of five megacycles best adapted to day conditions and the other, about three megacycles, best adapted to night. The equipment which has been available to the air transport industry previously has not been arranged so that the frequency could be changed during flight. It sometimes happened, therefore, that during transition periods between day and night frequencies, some of the planes with which a certain ground station had to communicate would be set for one frequency and others for the other. Under such conditions regular communication with airplanes became disrupted and position reports were missed.

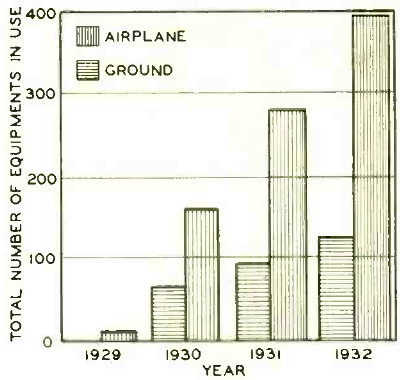


Fig. 2—Two-way radio telephone systems for airplanes have been in use for only a little over three years but have shown a rapid growth

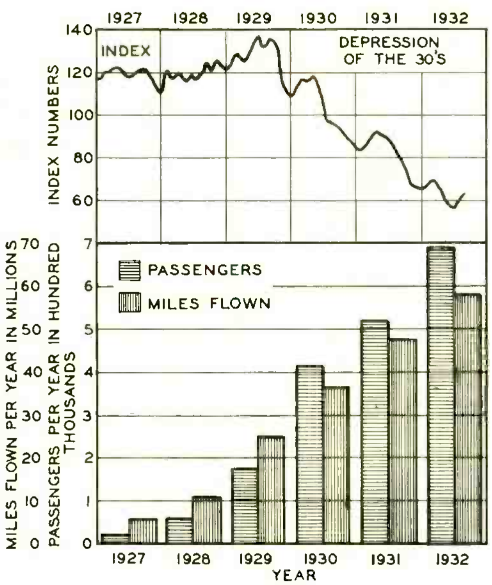


Fig. 1—Graph showing the rising trend of both miles flown and passengers carried and the falling trend of the index numbers of industrial production

Frequent conferences have been held between representatives of the larger transport companies, and the Western Electric Company and engineers of the Laboratories, and a close agreement has been reached regarding the requirements for radio telephone equipment for airplanes. As a result a new line of radio telephone equipment has been made available which, although embodying many features of the earlier apparatus, has a number of novel features and is greatly improved in many respects. Notable among these are provisions for changing the frequency while in flight and for greater selectivity in the receiver, the two problems of most immediate concern.

The change from day-time to night-time frequency or vice versa is accomplished by the operation of switches in the receiver and transmitter. These are connected mechanically and operated by the pilot through a single control. In planes where the transmitter and receiver are close to the pilot's position, the switches are controlled by a pull wire, but for greater distances, a flexible shaft drive is employed which shifts the switch in both receiver and transmitter at the same time. The connection of this shaft to the base structure of the apparatus is shown in Figure 3. This arrangement permits the shift between day and night conditions to be made at pre-established times regardless of where the plane happens to be.

Except for this frequency shifting arrangement and certain simplifications, the control is similar to that for the earlier equipment. The equipment is made ready for operation by two control switches. When one of these is thrown the two receivers are placed in operating condition, and when the other is thrown, the transmitter is made ready for operation. In either case, an interphone circuit is available between pilot and co-pilot. For this service the audio-frequency amplifier of the receiver is used to amplify the signals from the microphone. The complete equipment, including two receivers, a transmitter, and all accessories, is shown in Figure 4, where is shown also the flexible conduit used for the wiring between the various pieces of apparatus.

The method of obtaining improved selectivity in the receiver, and the other improvements in both transmitter and receiver are described in accompanying articles. Another new feature affecting the operation of the entire system is the provision of alternate types of power supply. One type is similar to that of the older radio system and employs dynamotors operating from the plane's 12-volt battery to furnish plate current to both the transmitter and receiver. The dynamotors have now been assembled with their accessory equipment on a detachable base, which makes instal-

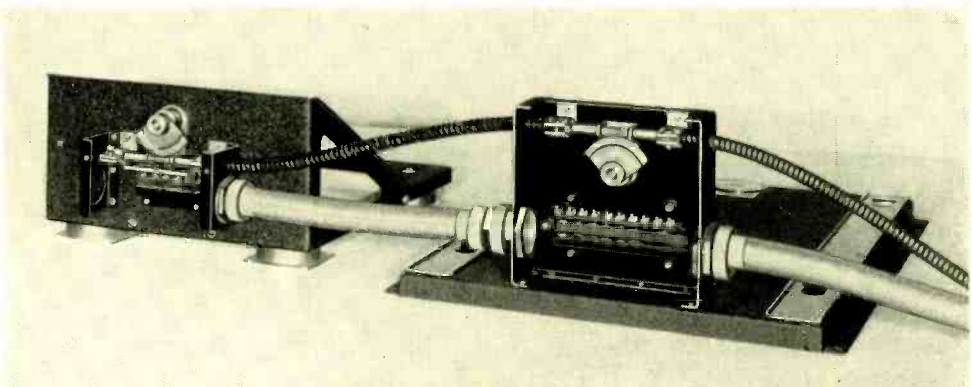


Fig. 3—A single flexible shaft drives, through a worm and segment, the frequency changing switch in both transmitter and receiver

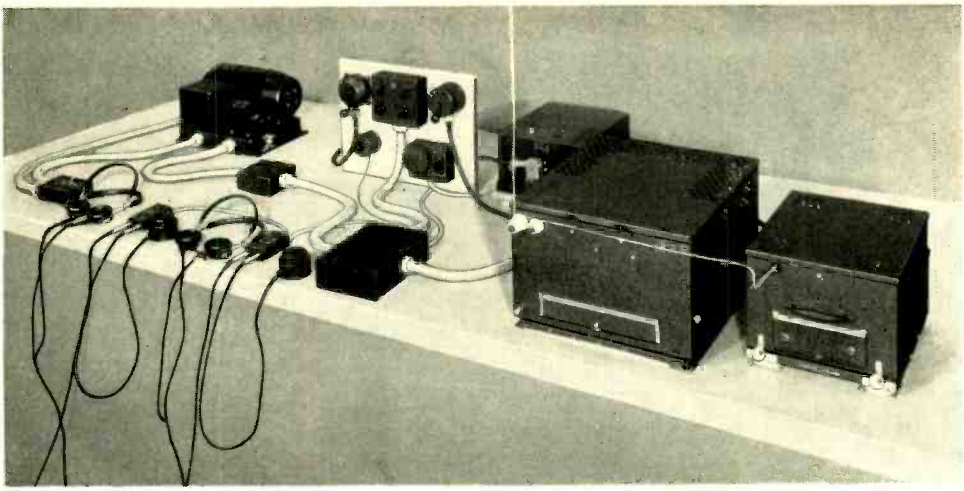


Fig. 4—The 208A radio telephone equipment. The main pieces of apparatus, from left to right, are: dynamotor power unit, controls, weather-and-beacon receiver, transmitter, receiver for two-way system

lation and inspection more convenient.

In the other and newer type, power is obtained from a double voltage engine-driven unit, shown in Figure 5, which may be employed as either a generator or dynamotor at the pilot's volition. Under normal operation the unit is operated through a centrifugal clutch as an engine-driven generator supplying both low voltage, for the filament and control circuits, and high voltage for the plate circuits of the transmitter. There is also sufficient capacity in the low voltage windings to keep the airplane storage battery in a charged condition. When the engine is running below some definite low speed, the clutch disengages and the pilot may pull a control handle which changes the electrical connections to enable it to be operated by the battery as a dynamotor. Under these conditions, and with a fully charged 65 ampere-hour battery, the radio equipment may be operated for two hours with the receiver continuously in service and the transmitter operating on a cycle of one minute on and five minutes off. With a smaller—35 ampere-hour—battery, which is adequate for the new equipment, a similar cycle may be maintained for one hour.

The present airplane equipment includes two fixed antennas. One of these is used for the low frequency receiver over which weather reports and beacon signals are received, and the other for the high frequency channel—both for transmitting and receiving. A push button on the new anti-noise microphone, developed by the Research Department and employed as part of the new telephone equipment, is employed to operate relays in the receiver and transmitter which connect the antenna to either receiver or transmitter as required and make the other circuit changes necessary for the transfer between talk and receive conditions.

Considerable attention has been given to making all the various pieces of apparatus readily removable for inspection, repairs, or replacement. All the major units—the transmitter and both of the receivers—are provided with separable bases which are permanently secured to the plane and to which the wiring is run. In these bases the wiring terminates in receptacles, and the radio units themselves have plugs which fit in the receptacles when the units are pushed into place. The base of the power unit has plugs at the ends of short flexible conduit connections which allow it also to be readily removed if desired.

Although the new equipment provides for multiple-frequency operation, and offers many other new features, it is possible for a transport operator to install it with the new power supply to weigh, complete, about fifteen per cent less than the equipment formerly available. Considerable savings will also follow from the convenient mountings and wiring arrangements, and from the smaller number of units to be installed. Maintenance savings can also be expected, due to the accessibility of adjustment points when the apparatus units have been removed, as they readily can be, to the service shop.

The cordial cooperation of the air transport companies, not only in the design of the new apparatus but in the more than seventy million miles of flight of the earlier models, has contributed notably to the excellence of this radio equipment. It may reasonably be expected that it will be an important factor in the reliability and safety on which the transport industry bases its expectation for future progress.

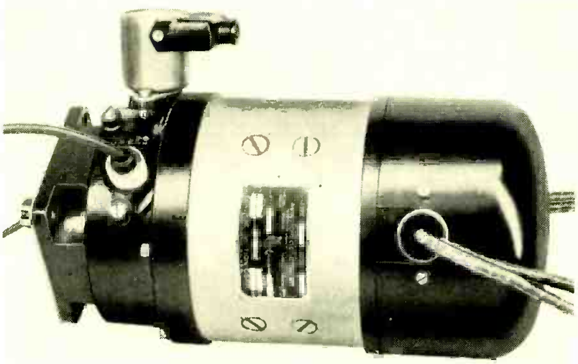


Fig. 5—A two-voltage generator dynamotor supplies power for the 208B system

A Three-Frequency Radio Telephone Transmitter for Airplanes

By W. C. TINUS
Radio Development

OPERATING experience with airplane radio telephone equipment during the last few years has served to emphasize the need for facilities permitting rapid change of the operating frequency. The large increase in night flying has made general the use by each transport company of at least two frequencies: one best suited to day conditions and one, to night. It is apparent that the transition from day to night frequency will result in confusion unless all stations on the system, including planes in flight, can change frequency simultaneously. In a new airplane transmitter which has been developed, therefore, provision is made for changing the frequency by operating a simple manual control. This allows the pilot to change from day to night frequency or vice versa at a preestablished time. No technical skill is required for this procedure as it involves no tuning operations whatever.

Besides this feature, the new transmitter—known as the 13-A—incorporates a third frequency channel which may be selected by the same control that changes from day to night frequencies. This arrangement contributes greatly to safety because all

Department of Commerce stations keep constant watch on 3105 kc, which frequency is not assigned to any transport company. By being able to transmit on 3105 kc, therefore, an airplane pilot can communicate at any time with a Department of Commerce station to ask for weather reports or other information or to request assistance in emergencies. These government stations reply on the weather broadcast frequency so the pilot can have two way communication with them at any time without requiring an additional channel in his high-frequency receiver. These outstanding improvements, as well as others in the control and maintenance features, arise from certain novel refinements both in the electrical circuits and in the mechanical design.

The principal circuit features of the new transmitter are shown in the simplified schematic of Figure 1. For clearness only one frequency channel is shown and the dc circuits are omitted. The radio frequency circuits consist of a crystal controlled oscillator, and two stages of amplification employing screen grid tubes. The use of these four-element tubes—especially designed for this service by H. E. Mendenhall—eliminates the delicate and troublesome neutralizing adjustment, which is very advantageous in portable apparatus.

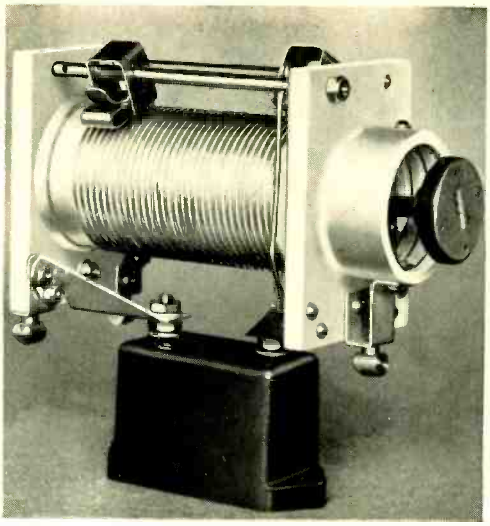


Fig. 2—A combination of coil and mica condenser forming the antenna coupling circuit is built as a single plug-in unit

Of considerable interest are the coupling transformers used between

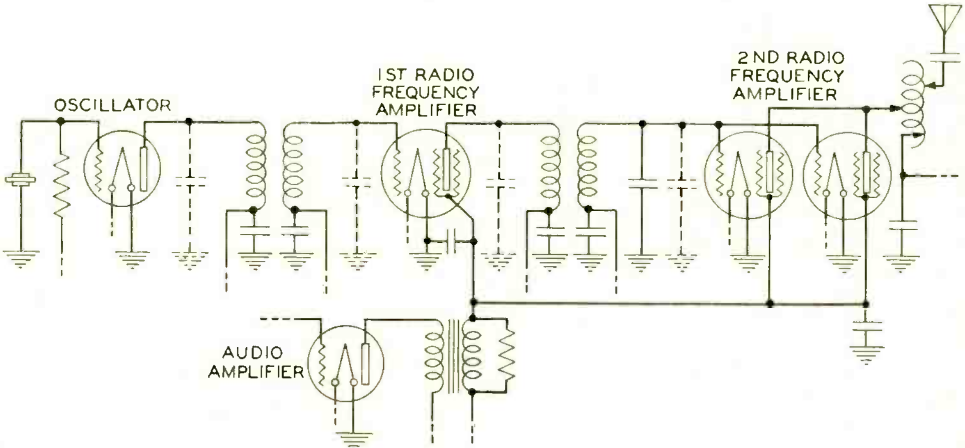


Fig. 1—Simplified schematic of transmitter showing only one frequency channel and omitting the dc circuits

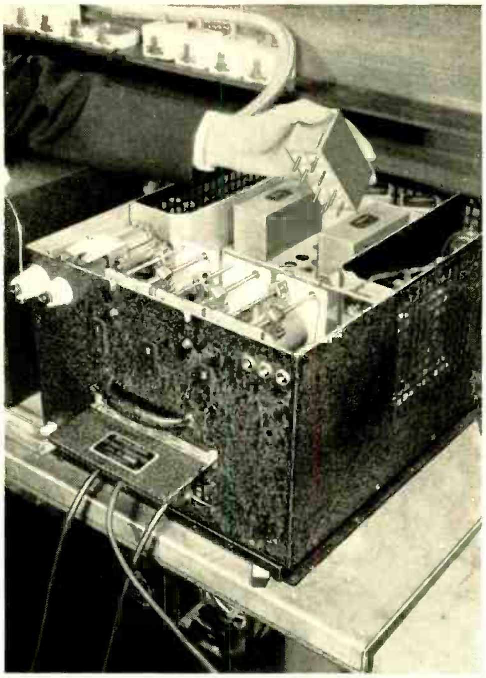


Fig. 3—The 13A radio telephone transmitter with cover removed showing one of the plug-in transformer units being inserted

ation night frequencies and another, the day frequencies. Transformers suited to other bands than those used for aircraft communication are also available. R. C. Newhouse was largely responsible for their development.

The crystals are also arranged in plug-in units, and may be seen behind the transformers in the photograph. The crystal is connected in the grid circuit of the oscillator tube, and operates at one-half of the desired output frequency. The primary of the transformer coupling the oscillator to the first amplifier presents a high inductive reactance to the plate of the oscillator at the crystal frequency, which is necessary to produce oscillations. The second harmonic of the crystal frequency is passed by this transformer and drives the first amplifier at output frequency. Similarly the other transformer passes the output frequency and drives the second amplifier.

Coupling between the second amplifier and the antenna is secured by a simple tuned circuit which must be adjusted in the field to tune various antennas of widely different characteristics. There are also three of these circuits which, consisting of a coil and a fixed mica condenser, are built in the form of a plug-in unit as

the oscillator and amplifier, and between the two amplifier stages. These are radio frequency transformers which in conjunction with the tube and wiring capacities (shown on the diagram as dotted condensers) form band pass filters. The two transformers for each of the three frequency channels are built as a single plug-in unit and may be seen in Figure 3. This arrangement not only eliminates tuning controls but results in a rugged and compact design. Such units are available for a number of bands varying from 550 to 800 kc in width and so located that one transformer covers practically all the avi-

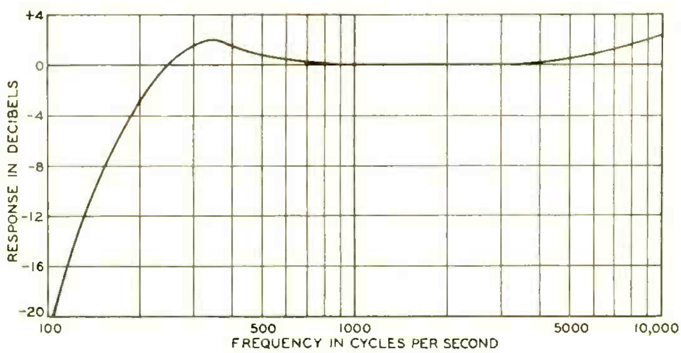


Fig. 4—Overall audio-frequency characteristic of transmitter

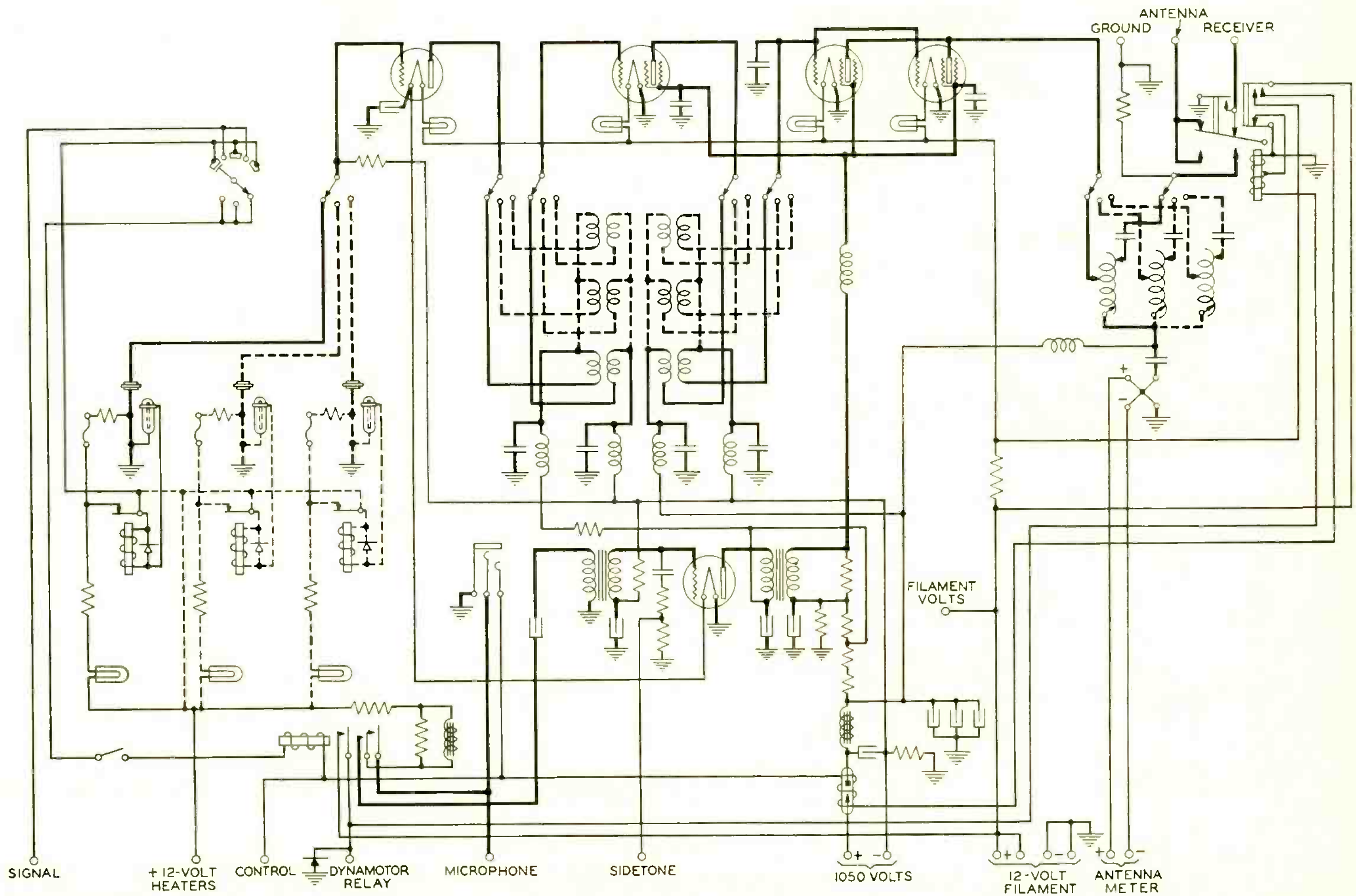


Fig. 5—Simplified complete schematic of transmitter with testing jacks omitted. Circuits for channels not in use shown with dotted lines

shown in Figure 2 and in the front of the transmitter in Figure 3. A continuous winding of bare tinned copper is wound on an isolantite form, and clips on slide rods can be set on any turn. When clamped in place they make good contact directly with the winding itself. Fine tuning is done by a small inductance wound on the inside of the coil form at the low potential end of the coil. This contact is adjusted with a screw-driver which may be inserted through a small door in the front of the transmitter.

Three-point switches are employed to select the desired crystal, pair of interstage transformers, and antenna coupling units, and all the switches are mechanically connected together and operated by a single control. An interlocking switch is also connected to the same control which prevents application of high voltage to the transmitter except when the switches are centered on one or another of the three channels. This switch also lights a lamp in the control unit near the pilot when the switches are off position.

A novel system of modulation is used in the new transmitter which permits deep modulation of the fifty watt carrier with only about one watt of audio-frequency power. This feature is directly responsible for the very satisfactory overall efficiency. The audio amplifier—like the oscillator a 205D tube—is employed to modulate the screen bias of both of the radio frequency amplifier stages. The overall characteristic of these two modulating amplifiers in cascade is nearly linear up to substantially complete modulation. With maximum modulation, the largest harmonic in the rectified output is less than 10% of the fundamental. The overall audio-frequency characteristic of the transmitter is shown in Figure 4. The low frequencies are purposely attenuated by a series condenser in the input circuit to reduce the amplitude of airplane noise picked up by the microphone.

Fig. 6—The new ballast lamp, employing a two-contact Ediswan base, is of unusually small size

A schematic circuit of the complete transmitter is shown in Figure 5. A thermocouple in the radio-frequency ground circuit is employed to operate an antenna ammeter near the pilot, who can therefore note whether the current is normal and whether it modulates when he speaks into the microphone—a positive assurance that his transmitting equipment is working properly. All grid and plate circuits are equipped with jacks (not shown on the diagram) accessible through a door on the front of the transmitter, which facilitate the location of trouble and routine checking by the maintenance men. An antenna relay, employed to switch the antenna between the transmitter and receiver, is made part of the transmitter to reduce the number of component parts of the system. The development of miniature ballast lamps by the group under J. R. Wilson has made it possible to use a lamp in each filament branch. The small size of these lamps may be judged from Figure 6.

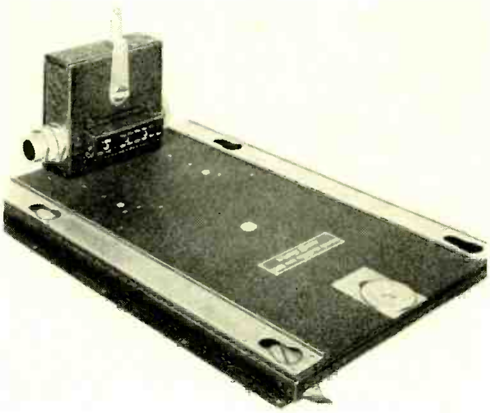


Fig. 7—Separable transmitter mounting which allows the transmitter to be readily removed or replaced as desired

Operation of the equipment requires the transmitter to stop immediately when the microphone button is released and to produce no noise in an adjacent receiver of very high gain. This was greatly facilitated by the development, in cooperation with V. L. Ronci, of a high vacuum relay which opens the 1050 volt plate supply. This relay is very small and light and is entirely safe to use where gasoline fumes may be present.

In the mechanical design of the transmitter, for which P. S. March was responsible, several novel features are incorporated. A separate mounting is designed for permanent installation in the airplane. An upright section at the rear of the mounting, shown in Figure 7, carries a multiple contact jack terminating all connections to the transmitter except the antenna, and a coupling to connect to the switches that select the frequency channel. All wiring is run to this mounting in either flexible or rigid conduit. A lever projecting from the front operates a cam which, when the transmitter is placed on the mounting, slides it back into contact with the receptacle and the frequency changing switch.

The entire structure of the transmitter itself is fabricated from sheet duralumin, and not only supports the apparatus but provides the necessary shielding. It is divided into two irregularly shaped compartments by interior partitions. Part of the outer casing is perforated and the space between the inner partition and the perforated section of the outer case forms a ventilated compartment into which is placed only the heat dissipating apparatus, such as the vacuum tubes, ballast lamps, resistances, and crystals. All other apparatus and wiring is completely enclosed for protection against dust and moisture. A new type of vitreous enamel resistor with rear connections was developed to keep the wiring out of the ventilated compartment.

The 13A radio transmitter is an excellent example of the great improvement that can be made in apparatus by a careful study of the most desirable form of the various component parts and their relative locations based on an intimate knowledge of service conditions. Even without a radical change in fundamental performance, the new transmitter is so superior to the old in many respects that it is expected to receive an enthusiastic reception from air transport operators.

A Crystal Control Superheterodyne Receiver

By H. B. FISCHER
Radio Development

SEVERAL years' experience with airplane radio telephone apparatus indicated, among other things, that there was need for greater selectivity in the receiver, and that the changes between night and day frequencies should be easy to make during a flight. Because of the limited width of the frequency band available for aviation telephone communication and of the large number of operating companies desiring frequency allocations, it has been necessary to assign channels with a frequency separation of only about one-tenth per cent. Since this is only one or two tenths of the separation of broadcast channels, the difficulty in selecting the channel desired without interference from the adjacent ones is evident. The requirement of being able to change frequencies while in flight arises because the ground station must be able to be in continual communication with a group of planes, some of which may be just beginning a flight and others about to terminate one. At transition periods between day and night conditions, a plane about to end a flight may be set for one frequency and a plane beginning a flight, at another. Without the ability to change frequency at a definite time while in the air, ready communication with the ground necessarily becomes handicapped.

In the development of the Western Electric 12A receiver, which is a part of the new aviation radio equipment, these two requirements have been fully and satisfactorily met. Certain other improvements which a study of past experience indicated to be desirable have also been made. In spite of these many improvements, the new receiver will weigh no more than the

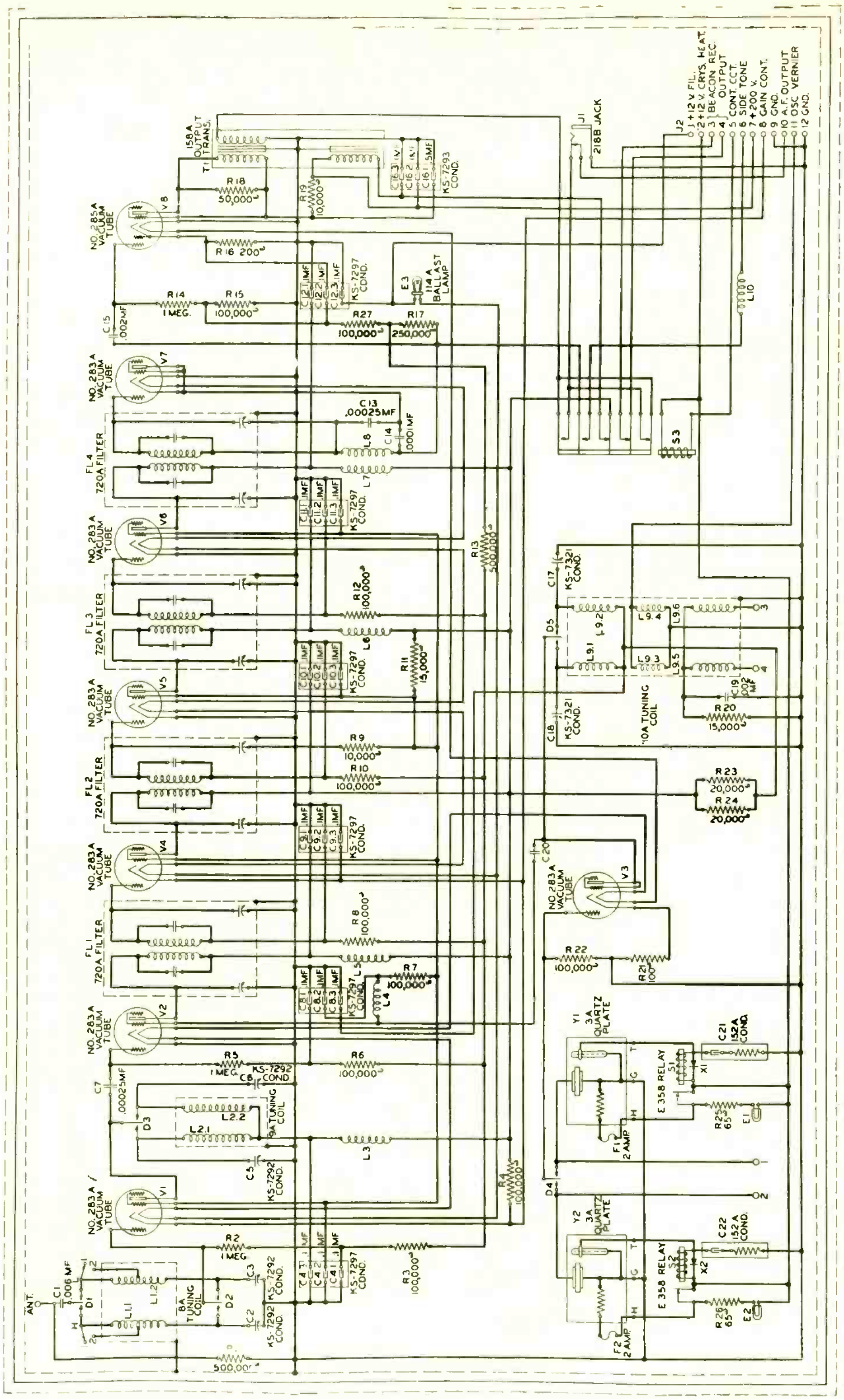


Fig. 1—Simplified schematic of the 12A receiver

9B receiver* formerly used for this service.

A schematic of the receiver is shown in Figure 1. To obtain the required degree of selectivity and sensitivity, a superheterodyne circuit is employed. From left to right in the diagram, there is one stage of tuned radio-frequency amplification, a first detector or modulator, three stages of intermediate frequency amplification at 385 kc, a detector and automatic volume control tube, and one stage of audio frequency amplification. A separate tuned circuit for each frequency is employed for the radio frequency stage and for the oscillator. Operation of a shifting mechanism selects the proper circuits for the frequency desired, the circuits having been properly tuned while the plane was on the ground.

In any radio receiver the usable sensitivity is limited by the tube and circuit noises. When this limit has been reached, sensitivity to still weaker signals is obtainable only by increasing the voltage input. For a given field strength, the voltage induced in a given antenna is fixed, but the voltage across a tuned circuit in series with the antenna can be much greater. Antennas ordinarily used for airplanes have a comparatively low resistance, and so lend themselves to the series tuning which is employed in this receiver with excellent effect.

Western Electric quartz plates are employed for controlling the frequency of the beating oscillator, thus insuring the correct frequency for satisfactory operation under all conditions and without attention on the part of the operator. Two oscillators are provided, and the one required is selected by the operation of the same control that selects the proper tuned circuits.

Under some operating conditions the high degree of frequency stability and freedom from attention on the part of the operator provided by the quartz plates may not be required. The 12A receiver has therefore been designed so that in such cases a tuning unit, either the 8A or 8B, may be used in place of the quartz plates. These are plug-in tuned circuits whose constants are much more stable than are those of ordinary tuned circuits. The coil is wound on an isolantite form, and the adjustable condenser has a thermostatic metal plate to reduce variations due to temperature changes. The units are mounted in moisture proof aluminum cans to avoid changes in the oscillator frequency caused by changes in humidity.

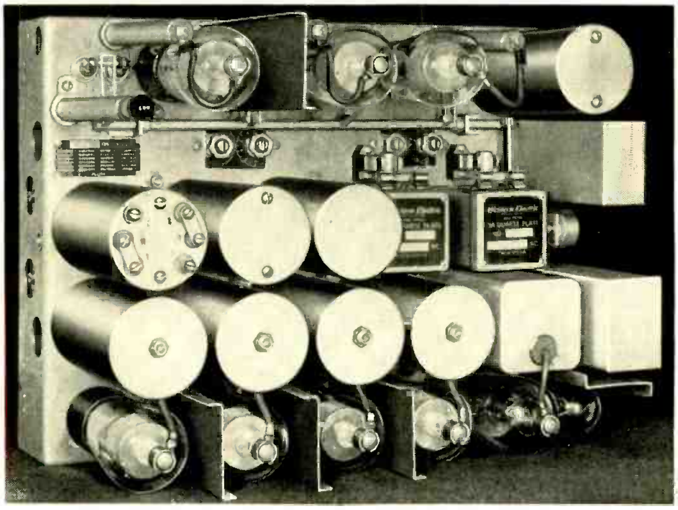


Fig. 2—Tuned transformers in cylindrical cans are placed adjacent to the tubes with which they are associated

*Record, *October*, 1930, *p*.71.

These precautions, together with the careful design of the oscillator circuit, minimize frequency variations caused by changes in the supply voltage, and provide a high degree of frequency stability. Small variations do occur, however, and a vernier condenser is required to compensate for the frequency drift. To avoid the use of a mechanical drive for the vernier when the receiver is controlled from a remote point, the vernier condenser is located at the operating point and connected to the set through a shielded radio-frequency transmission line of low impedance.

To obtain the high degree of selectivity required, three intermediate-frequency amplifier tubes with four double tuned transformers are employed. Each such double tuned transformer comprises a filter section and, mounted in an aluminum shield, is placed next to the amplifier tube, as may be seen in Figure 2. The fourth tuned transformer is connected to the detector which operates as a two-element rectifier and not only supplies signal output, but furnishes voltage for the automatic volume control system as well.

All but the audio frequency tube are the recently developed Western Electric 283A tubes, which have variable mu and high gain. The detector and oscillator are operated as two and three element tubes respectively by connecting certain electrodes together. By this arrangement the number of different types of tubes is reduced. For the audio frequency stage a 285A tube is employed. This is a pentode capable of delivering a sufficiently high output for the satisfactory operation of several pairs of headphones. When the receiver is used as part of an airplane system, this tube also acts as the amplifier for the side tone circuit when the transmitter is operated. A relay in the receiver makes the necessary change in connections when the button on the microphone is pushed.

Automatic gain control, widely used with present-day broadcast receivers, is even more important with airplane receivers, since in addition to the usual fading due to variation in the transmission path, there is a large change in signal strength due to the travel of the plane. With the system employed in the 12A receiver there is a barely noticeable change in audio output with a variation in signal input of 10,000 to 1. Even with this wide range in automatic control, however, a certain amount of manual control is desirable. An input in excess of half a volt is too great to be properly

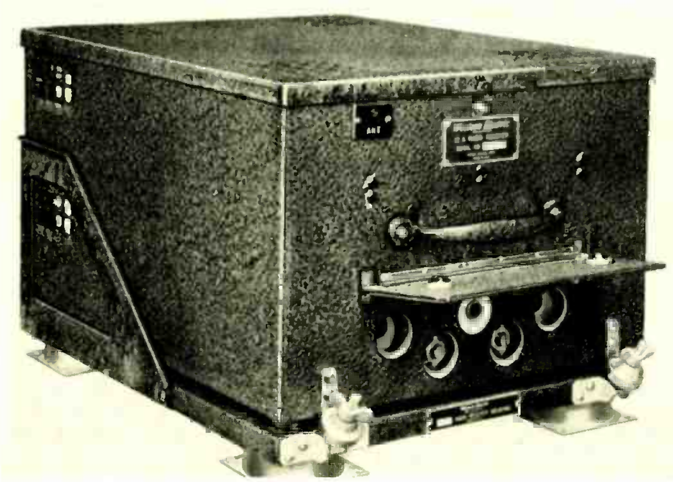


Fig. 3—The 12A receiver showing door on front and the shock-proof base on which it mounts

h by the automatic control, and since voltages of this magnitude may be applied when the plane is flying close to the transmitter, a manual control is provided near the operator's position, where it may be adjusted as required. Under normal conditions no adjustment is necessary during flight. A variable level control, also, is provided to allow the operator to adjust the headset volume to a comfortable value.

The power required for the heaters of the vacuum tubes is 3.2 amperes at 12 volts. A ballast lamp in the heater supply circuit provides adequate regulation for applied voltages from 11.5 to 14.5 volts. When the quartz plates are employed for frequency control, an additional intermittent drain of 2.4 amperes is required at the same voltage. For the plates and screens some 40 milliamperes is required at 200 volts, which is furnished by a small dynamotor operated from the battery.

To secure rigidity and still allow easy access to the various parts of the circuit, the apparatus is mounted on a dished aluminum chassis, as may be seen in Figure 2. The radio-frequency tuning coils, the intermediate frequency filters, the quartz crystal frequency controls, the filter system for the power supply, the various relays, and all vacuum tubes are mounted on the upper or flush surface of this chassis, while the radio-frequency tuning condensers, the high frequency choke coils, and the associated by-pass condensers are mounted underneath on the dished side of the chassis. An aluminum box surrounds the chassis and apparatus to provide mechanical protection and overall shielding. A removable top gives access to the tubes and frequency controls, and a small hinged door on the front gives access to the antenna tuning condensers and the indicator lamps of the crystal heater, as shown in Figure 3.

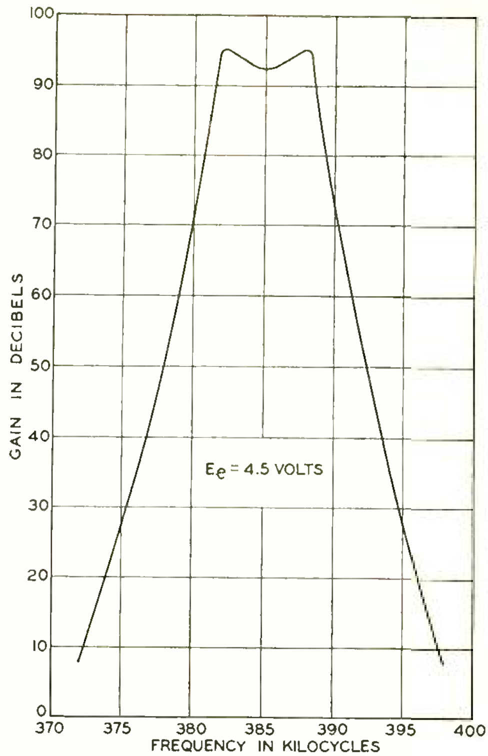


Fig. 4—Selectivity of 12A receiver

The complete receiver is placed on a base which has rubber shock proofing to protect the receiver from vibration normally found in an airplane. This mounting is permanently installed in the plane and to it is run the power supply cable, the leads of which terminate in a multicontact receptacle to which a plug on the receiver makes contact when the receiver is placed in the mounting. The frequency changing mechanism is also part of the mounting and connects to the receiver through a coupling. This arrangement permits the receiver to be readily removed for repair or replacement without requiring any disturbance of the permanent wiring.

One of the outstanding characteristics of this receiver is its high value of selectivity. The response from an interfering signal only ten kilocycles from the desired one is about 1/1000 of that due to the desired signal. A selectivity curve is shown in Figure 4. Although the receivers used for this service at the ground stations have similar selectivity, it far surpasses anything previously attained in airplane sets.

The sensitivity obtained in the three stages of intermediate-frequency amplification and one of radio-frequency, is very high. An input of one microvolt at the antenna gives an output of over twelve milliwatts, which is more than sufficient for headphone reception. Such high sensitivity is not required for normal operation, but it insures a sufficient reserve of amplification to give satisfactory reception under abnormal conditions. The outstanding performance of this receiver, together with its simplicity of operation, should be of considerable value in increasing the reliability of aviation communication.

Extensions of Telephone Service

Three of the four corners of the globe have seen in the past two months extensions of service which place them in telephone reach of Bell System subscribers.

On March 20 the telephones of Costa Rica were tied to the Bell System by a radio link between the American Telephone and Telegraph Company's new station at Miami and the station at Cartago, near San Jose, of the International Radio Company of Costa Rica.

On March 29 the Bell System's radio stations in California, which have been operating on the link to the Hawaiian Islands, undertook communication with the Philippine Islands as well. Radio facilities in the Philippines are provided by the Radio Corporation of America, whose stations tie in with the wire lines of the Philippine Long Distance Telephone Company.

On April 7 the cities of Jerusalem, Haifa and Jaffa were placed within reach of American telephones by arrangements for connecting the regular transatlantic radiotelephone circuits with a short-wave channel between London and Cairo, Egypt, and thus with land wire facilities to Palestine.

A three-minute conversation between New York and Palestine costs \$37.50, and between New York and San Jose, Costa Rica, \$21. A similar conversation between San Francisco and Manila costs \$30.

Artificial Anthracite

By K. H. STORKS
Chemical Laboratories

RECENT developments in high-pressure technique have led to the synthesis on a commercial scale of several materials which were formerly obtainable only from natural sources. As the limit of possible pressures has been raised, many investigators have attempted to imitate geological processes, including those by which coal is formed. Constituting as it does the best material yet found for the preparation of transmitter carbon, the possibility of discovering and reproducing Nature's method of manufacturing anthracite is alluring to the telephone chemist.

Current theories of coal formation have already been summarized in the RECORD*. Past attempts to reproduce this procedure have been at the hands of men primarily interested in checking these theories, in improving their understanding of the formation of bituminous coals, or in the manufacture of oils from coal and hydrogen. Their reports of the formation of anthracite-like substances by the application of heat and pressure to various starting materials gave encouragement to these Laboratories to extend the range of investigation, with the production of anthracite-like coals more definitely in mind.

The most generally accepted starting material is vegetation high in cellulose content but also containing lignin, such as the ordinary woods. The lignin which constitutes the binder in such vegetation may be important in forming a binder in the ultimate coal, but vegetation in which the lignin content is high probably produces the brown coals rather than anthracite. In the formation of anthracite and other high rank coals some materials other than lignin have been important. These are supposed to be the products resulting from the decomposition of the cellulosic constituents of the original vegetation either by the action of bacteria or

Fig. 1—Closing the autoclave in which the raw materials for artificial anthracite were pretreated at low temperatures

*RECORD, *January*, 1932, *p.* 150.

yeasts or by the prolonged influence of temperature and pressure. Known to be effective in the decomposition of vegetation, certain types of bacteria have probably been important in the initial chemical changes occurring in the formation of coals. However it is possible in the laboratory to bring about similar changes by the effect of temperature and pressure alone, and at a great saving of time.

Wood begins to decompose at temperatures a few degrees above 100° Centigrade. As the temperature rises, the decomposition increases, and at about 300° C. a reaction takes place accompanied by the evolution of heat and of large quantities of gases and liquids, chiefly water vapor, oxides of carbon, methane and tar when no added pressure is applied. At 400° C. under atmospheric pressure the decomposition is complete, and the solid residue of charcoal is nearly pure carbon. Applying pressure to this charcoal fails to produce anything resembling anthracite, at least at the temperatures used in this investigation, probably because the binding materials have been destroyed.

When the same progressive heating is carried out in a sealed tube, the reaction products build up a considerable pressure, the carbonization is less nearly complete, and the proportion of solid and liquid to gaseous products is higher. The residual peat-like solid, of rather low carbon content, is probably very similar to that formed at an early stage in the natural conversion of vegetation to coal. It was therefore decided to attempt the synthesis of anthracite by pretreating the raw material so as to convert it into something resembling peat, and then subject this peat to higher temperatures and pressures.

The raw materials used include birch wood, cotton cloth, sugar, and jute fiber of high lignin content. For pretreatment the material was placed in a special electrically heated steel autoclave (Figure 1), along with varying quantities of water. The water adds somewhat to the pressure developed, prevents local heating, and at elevated temperature and pressure provides a slightly acid medium which has been suggested as having a catalytic effect on the carbonization. Pretreatments of different samples have covered the range of temperatures from 180° C. to 300° C., and of pressures from 800 to 10,000 pounds per square inch.

At temperatures up to 230° C. the products of this pretreatment were not at all like coal but quite like peat: brown in color, still showing much of the original structure, readily powdered, and with a hydrogen content of about six per cent. Neither these nor the products of pretreatment at higher temperature could be converted to anthracite-like coal at the lower temperatures of final treatment. The gases produced during pretreatment consisted chiefly of carbon dioxide, mixed with amounts of carbon monoxide and methane which increased with the treating temperature. Only small amounts of tar were produced, far less than by heating at atmospheric pressure.

For final treatment, charges of 100 to 200 grams of the pretreated materials were placed between two plungers in a heavy steel cylinder, heated electrically, and subjected to pressure in a hydraulic press (Figure 2). To extend to the utmost the range of temperatures and pressures which could be used, the cylinder was lined with a special chrome-nickel steel, developed by the Society of Automotive Engineers, which will retain good

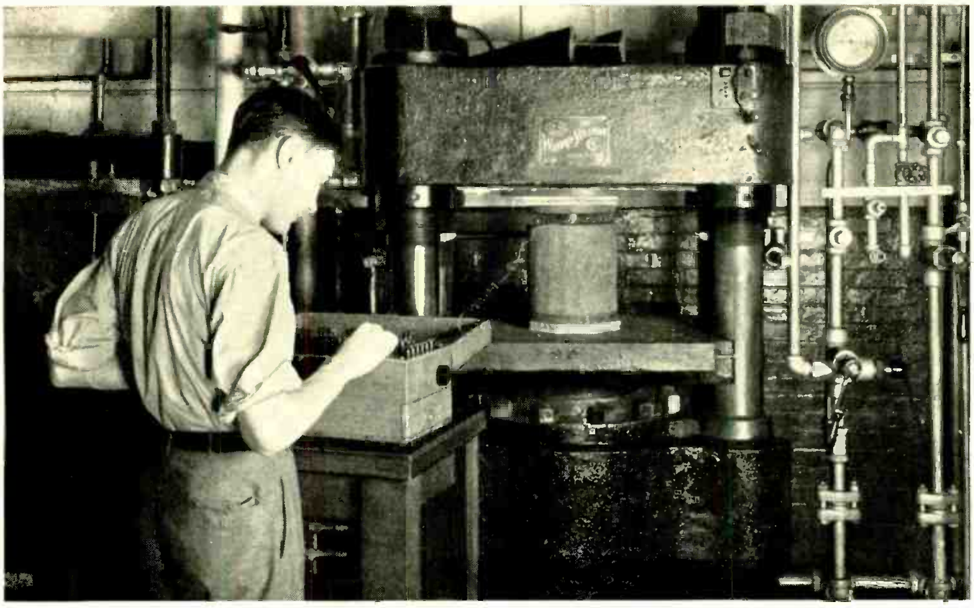


Fig. 2—In the final step in producing experimental samples of artificial anthracite, the materials were subjected to high temperatures and high pressures in a steel cylinder

hardness and elasticity under 100,000 pounds per square inch up to 500° C. The clearance between the plungers and the cylinder walls was made ample to permit the escape of gases, since it is believed that rock fissures and lines of fracture permit such escape in the natural formation of anthracite. Final treatments in this bomb covered a range of pressures up to 56,700 pounds per square inch.

At the outset of the experiments high pressure was applied to the charges while they were being heated. It was soon found that a strong reaction evolving heat set in at about 320° C., accompanied by the voluminous escape of gases which would often blow most of the charge out past the piston. In some cases a shell of coal would be formed against the walls of the bomb which prevented the escape of gas, with the result that the center of the charge was dull, porous and crumbly. Unsatisfactory also was the technique of applying high pressure only after the charge had been held at 320° C. for a couple of hours.

It was finally found best to hold the charge under low pressure at the final operating temperature of 400° C. to 450° C. for about an hour, and then to apply high pressure gradually and to maintain this pressure during the heating and while the charge was later allowed to cool to room temperature. In this manner uniform and firmly bound products were obtained.

The majority of the products, and the most successful, were obtained from wood. Many of the samples showed the lustre of natural anthracite, had comparable hardness and apparent density, and fractured to leave conchoidal surfaces. They burned quite slowly in a slow stream of pure oxygen, with little or no visible flame, and negligible evolution of tar and coal gas. The residual ash, weighing usually less than one per cent of the original sample, consisted mostly of iron oxide, probably because of the use of iron vessels in pretreatment and final treatment. The content of carbon in the best samples obtained varied from 71 to 89 per cent, and of hydrogen from 3.9 to 3.2 per cent, well within the reported range of lower grade natural anthracites but not sufficiently high in carbon nor low in hydrogen to correspond with anthracites of the best grade.

The hydrogen content was lower, the higher the temperature of final treatment; and when this content was plotted against temperature, the downward slope of the curve became greater above 400 degrees Centigrade. Greater lengths of treatment at any fixed temperature also decreased the hydrogen content, but the rate of decrease diminished as the period of treatment was prolonged. The variation in hydrogen content was such as to offer little encouragement to increasing the pressure, and indicated that the low hydrogen content of certain natural anthracites must be due to factors other than pressure alone.

Samples of the more promising products were ground, screened, roasted by the methods used in preparing transmitter carbon.* The ground and screened material did not display the mechanical uniformity of the natural product. Although it did not show excessive porosity, it contained many granules either flat or bearing pronounced promontories. Roasting brought about considerable shrinkage but no coking. Almost without exception, the resulting materials had resistances lower than that of transmitter carbon, in extreme cases approaching that of graphite. The efficiencies of the materials as modulators were also lower than the standard, approaching non-modulation in materials with resistance as low as graphite.

Ultimate success in the project waits upon a satisfactory adjustment of both the chemical and the physical properties of the final material. The results already obtained indicate that the chemical adjustment depends largely upon the final treatment, where temperature is the most important factor provided the period of its application is sufficiently long. In determining the physical characteristics, both the preliminary and final treatments are important, the former considerably influencing fracture and binding.

It seems probable that further experimentation, varying the many determining factors, would ultimately reveal a procedure for producing anthracite at least as good as the natural. Necessarily empirical and lengthy, such experimentation appears at present unjustified since the condition of natural beds of anthracite today suggests no pressing need for substitutes. The experiments so far performed have broken the way to filling the need when it arises, and have meanwhile contributed toward a better understanding of the fundamental principles of coal formation and of how to select the best anthracite for manufacture into transmitter carbon.

*Record, *February* 1932, *p.* 200.

Contributors to This Issue

D. K. Martin had been actively interested and engaged in radio work before getting his B.S. degree, in 1916, from the Polytechnic College of Engineering at Oakland, California. Shortly after graduation he went to Alaska for the Alaska Packers Association where he was occupied with the installation and operation of their radio facilities. During the World War he was an Ensign in the United States Navy, spending much of his time as radio instructor. In 1919 he joined the American Telephone and Telegraph Company where he continued his radio work in the Department of Development and Research. Transferring to the Laboratories in 1928 he engaged in the development of aircraft radio apparatus, and at present he is supervisor of the group which is handling radio transmission studies and radio beacons for airways.

D. K. Martin

W. C. Tinus began his radio career with an amateur radio station immediately after the war. He was later with several of the early broadcasting stations in the southwest and also served at sea as a radio operator. He received the B.S. degree in Electrical Engineering from Texas Agricultural and Mechanical College in 1928 and then joined the Technical Staff of these Laboratories. Since that time he has been concerned with the development of airplane radio equipment and with its application to the rapidly growing commercial airlines throughout the United States.

H. B. Fischer received a B.S. degree in Electrical Engineering from the University of Wisconsin in 1924

W. C. Tinus

H. B. Fischer

K. H. Storks

and immediately joined the Technical Staff of the Laboratories. With the radio department he first worked on broadcast receivers, but after the development of aircraft communication apparatus was started, he engaged in the design of aviation receivers. At the present time, he is in charge of the group developing radio receivers for mobile systems.

K. H. Storks received the B.S. degree in 1930 from Coe College, Cedar Rapids, Iowa, and joined the staff of the Laboratories' Chemical Department. His first work here was on carbon for protector blocks, and later he undertook the development of artificial anthracite. Since the completion of this work, which he describes in this issue of the Record, he has been investigating the properties of synthetic organic insulating materials at the Summit Laboratory.

Telephone Between Airplane and Trawler

The first call from an airplane in flight through the Boston Marine Radiotelephone system was made on Friday, March 10, when Capt. A. R. Brooks, piloting the Laboratories' trimotor plane, talked with the skipper of the "Gertrude M. Fauci," a trawler then fishing on Georges Bank, about 200 miles offshore. The call passed through the Mendham laboratory and land lines via Boston to the marine station of the New England Telephone and Telegraph Company at Green Harbor, Mass.