BELL LABORATORIES RECORD

RECEIVERS FOR AERONAUTICAL RADIO

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ARTICULATION TESTING

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In this Issue

BELL LABORATORIES RECORD

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New Airport Receivers

By H. B. FISCHER
Radio Development

AN installation of a No. 11B Radio Receiver at the American Airways' Hangar, Newark Airport, emphasizes the value of this recent contribution of the Laboratories to commercial aviation. Two-way telephonic communication between aircraft and ground has grown very rapidly in recent years. Today all the large commercial aircraft operating companies, engaged in the transportation of passengers and mail, employ such two-way radio telephone systems, and put them to a variety of uses. Over them the position of the ship is reported at regular intervals, weather information is secured to supplement that received from the beacon stations maintained by the Department of Commerce, and their constant availability greatly simplifies the dispatching procedure. In addition to these routine uses, the two-way system is of great value in emergencies such as a forced landing.

Foreseeing the desirability of such service, the Laboratories developed the necessary apparatus* several years ago, and it was widely sold by the Western Electric Company. The equipment provided was very satisfactory under the conditions existing at that time, but the rapid increase in the number of such systems installed has considerably changed the situation. Because of the many channels that must now be accommodated

*Record, *October*, 1932, *pp.* 59-76.

within the comparatively narrow band of frequencies allotted to two-way aircraft communication, local stations are frequently only from twenty to thirty kilocycles apart. Since the lowest aircraft frequency is three thousand kilocycles, this means that the frequency separation is less than one per cent. Anyone who has ever had difficulty in separating stations in the broadcast range, where the spacing between local stations is from five to ten per cent, can imagine the difficulty when the separation is less than one per cent.

The earlier receivers employed for this service were not selective enough to be satisfactorily used under these conditions. An extended program of experimental work on the part of the Laboratories, however, resulted in an airport receiver for this class of service, known as the 11 type, which

Fig. 1—The 11B receiver, like the 11A, mounts in the 6A cabinet, which is rugged and self supporting

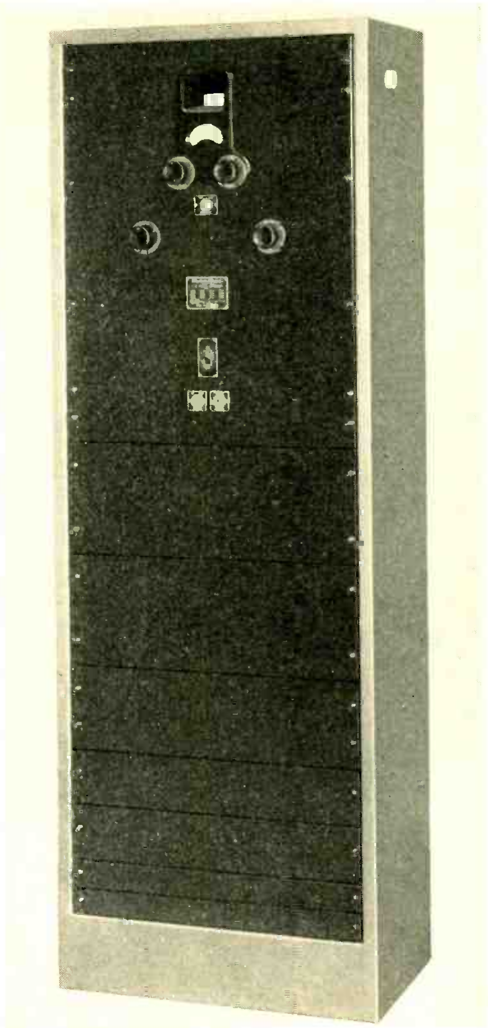


Fig. 2—The 11A receiver differs in appearance from the 11B chiefly in having a gang-tuning dial on the front panel

meets all requirements. It is of the highly selective superheterodyne type, while the earlier receiver—the 9B—was of the tuned radio-frequency type. This receiver is made in two forms: the 11A and 11B. The former is continuously tunable over the frequency range from 2700 to 6500 cycles, and is designed for use where there is no great amount of electrical noise in the immediate vicinity. The 11B, on the other hand, has two fixed frequencies,

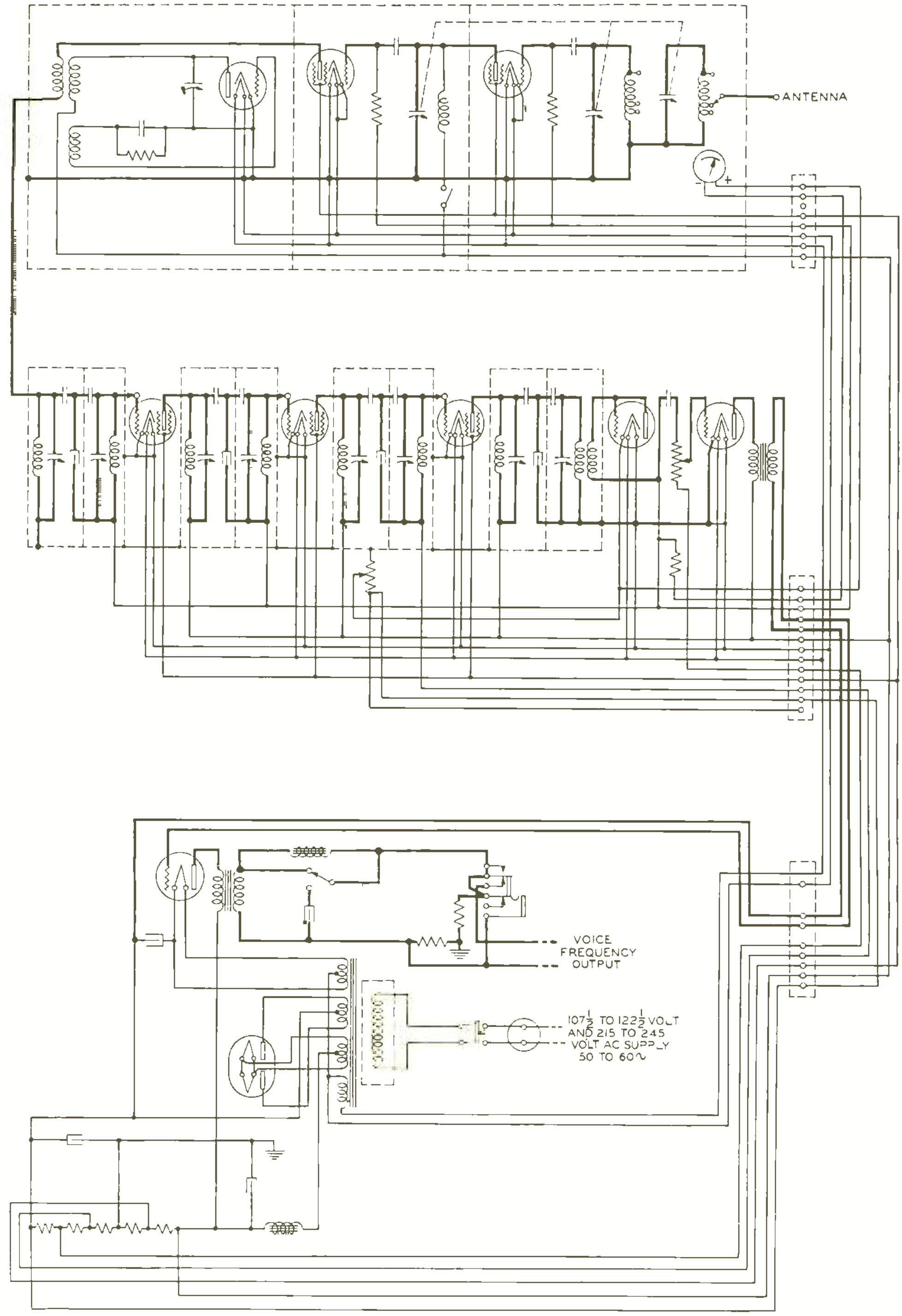


Fig. 3—Simplified schematic diagram of the 11A radio receiver

to accommodate the two frequencies used by a system, and is designed to be located at a distance from the airport where it will be out of reach of any disturbances that may exist near the airport.

The selective characteristics and mechanical arrangement of the two forms are essentially the same. Both are mounted in self-supporting metal cabinets, the 11B being shown in Figure 1 and the 11A in Figure 2. The circuit of the 11A, which is like that of the 11B except as noted later, is shown in Figure 3. It consists of one stage of tuned radio-frequency amplification, a modulator, an oscillator, three stages of intermediate-frequency amplification, a rectifier used as a detector and volume control, and two stages of audio-frequency amplification.

To obtain the extremely high overall selectivity required by the very severe service conditions, two types of selectivity must be provided. It is necessary first, to provide sufficient selectivity so that no signal is heard from stations operating at a frequency as little as twenty kilocycles from that of the wanted station. This selectivity is obtained in the intermediate-frequency amplifier, which operates at 385 kilocycles. This is known as "close-up" selectivity since it is concerned with signals very close in frequency to that of the wanted signals. The characteristics of the new receiver for this type of selectivity are given in Figure 4, which shows that a signal only ten kilocycles from the wanted signal is attenuated about 70 db.

In addition to this close-up selectivity, which is concerned with side bands very close to the desired one, selectivity in the radio-frequency circuits must be provided to prevent adjacent carriers, differing from the desired frequency by more than 30 kc,

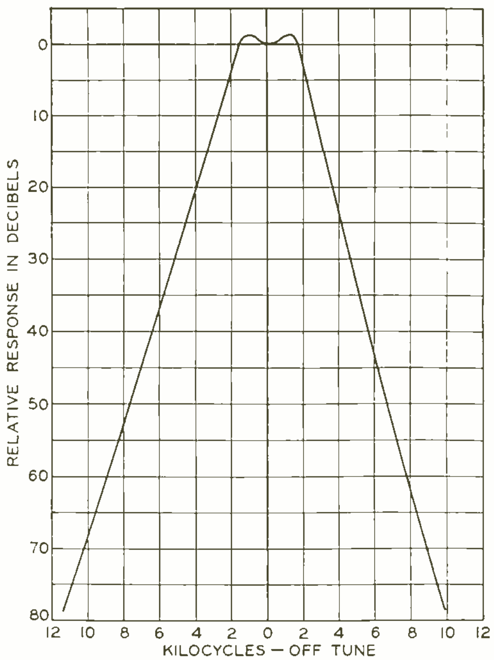


Fig. 4—Close-up selectivity of the 11 type receiver

from entering the modulator in sufficient amount to produce objectionable cross-modulation. If this were not done, some of the frequencies of the cross-modulations might be of a value to be passed and amplified by the intermediate-frequency stage, and so would appear as undesired frequencies in the audio output. Discrimination of this type is performed by tuned radio-frequency circuits. The high value of overall selectivity obtained by this arrangement is given in Figure 5, which shows the values of undesired signals, at various frequency separations from the desired signal, which will produce an interfering signal 20 db down on a wanted signal of 50 microvolts.

High-frequency signals generally have a tendency to vary widely in level because of changes in the transmission path. Also, the airplane from which the signals are being received is changing its distance from the ground stations, which introduces a change in signal level in addition to the fading caused by change in path. The new receiver, therefore, is provided with an automatic gain control which maintains a substantially constant output for wide variation in signal input. To obtain this regulation, a voltage is developed in the detector circuit, which is proportional to, but considerably greater than, the incoming carrier, and this voltage is used to adjust the grid bias on the high-frequency tubes and thus, by changing the gain, to maintain the desired output for different values of signal input. Such automatic volume control makes the operation of the receiver much more satisfactory since it is not necessary for the operator to change the gain except at infrequent intervals.

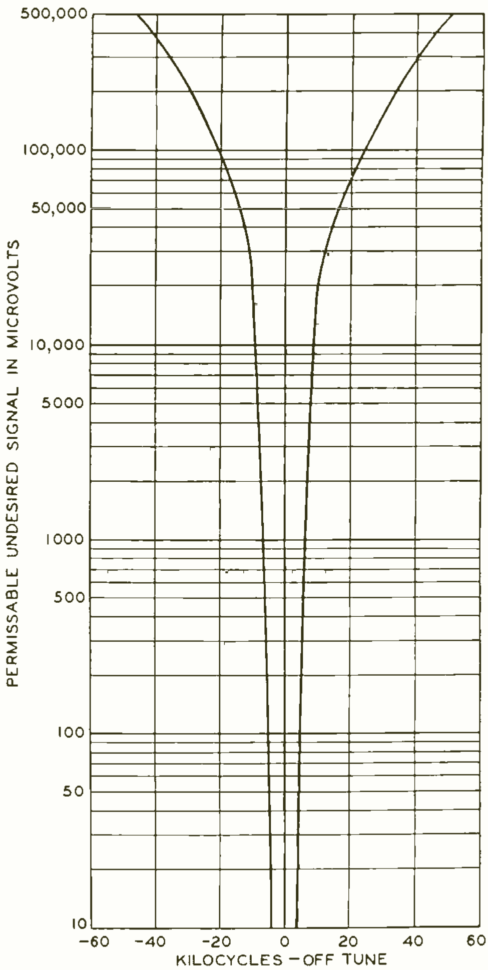


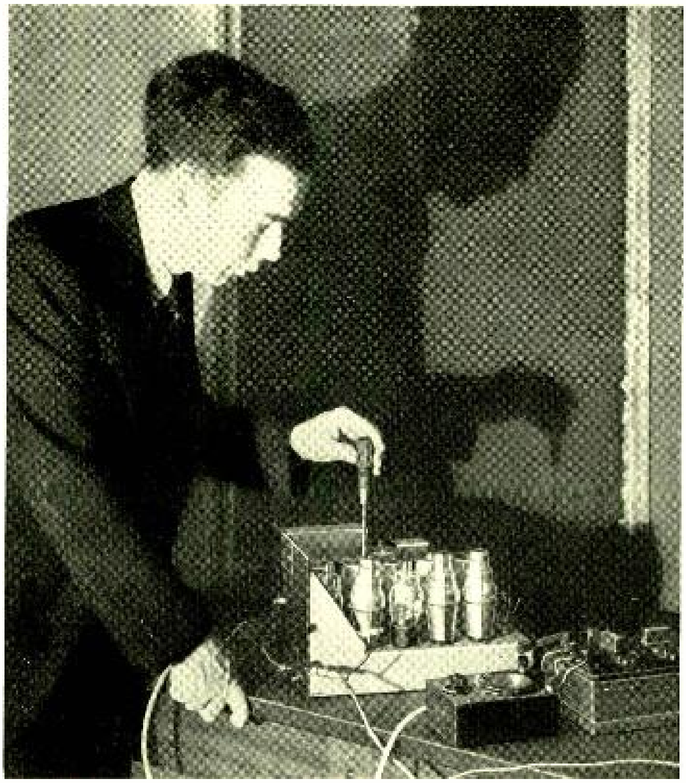
Fig. 5—Overall selectivity of the 11 *type receiver*

The three stages of high-gain intermediate-frequency amplification in addition to the radio-frequency amplification, provide a higher sensitivity than is normally required. The result is a reserve of gain which insures satisfactory operation under abnormal conditions. A signal input of one microvolt is sufficient to give full output at the loud speaker.

At a busy airport, where various types of electrical machines are operated at frequent intervals, thus producing a considerable amount of electrical noise, the operation of a sensitive receiver would be unsatisfactory. For such airports, therefore, it is desirable to locate the receiver at some distance away, and to operate it over a wire line. It was to meet such conditions that the 11B receiver was designed. Although continuous tuning over the operating band is desirable, the additional cost required to obtain it with a remote-controlled set is not justified. Since each operating company employs only two frequencies in its communication system, the 11B receiver is designed for operation at either of the frequencies—the frequency desired being selected by operating a dial at the airport. The two frequencies employed may be changed manually to any frequency within the band from 2700 kc to 6500 kc as is shown being done in Figure 1.

The chief differences in circuit between the 11A and 11B receivers are in the radio-frequency amplifier. Since it is not necessary to have a unitary control in a fixed-frequency receiver, individually adjustable condensers are provided for each tuned circuit, and a switching relay is associated with each by which it may be shifted from high to low frequency or vice versa. The beating oscillator is maintained at a constant frequency by the use of Western Electric quartz plates. Once adjusted, no further tuning of any kind is required for satisfactory reception.

A regular telephone line is employed for carrying the voice currents, and for controlling the receiver. Pulses for shifting the receiver from one to the other of its two frequencies, and for varying its sensitivity are sent over this line from a control unit located at the operating point. To change frequency and control the sensitivity, the operator merely operates a dial. The output of the receiver is sufficient to give satisfactory head-set operation at the airport. Should loud-speaker operation be desirable, some audio-frequency amplification is required at the airport. Although the 11B receiver was designed for locations remote from the airport, it may be used as a local receiver when it is desirable, by the elimination of tuning controls, to insure that the receiver is always tuned to the correct frequency without attention from the operator.



A Highly Selective Weather and Beacon Radio Receiver for Airplane Use

By W. E. REICHLE
Radio Development

THE remarkable regularity with which air transport companies are adhering to fixed schedules is due, to a large extent, to the weather and beacon receiver which is standard equipment on every mail and passenger airplane. With this receiver the pilot can make use of the frequent weather broadcasts transmitted by the Department of Commerce, and he can employ the beacon signals to guide him to his destination. In addition to the services rendered by the beacon and weather stations, operated by the government, some of the air transport companies are installing low-power beacon transmitters of their own, which are located at the airport and mark the runway of the field so as to help the pilot to land the airplane although the visibility may be extremely poor.

Since the number of beacon and weather transmitters is constantly increasing, the selectivity of the radio receiver is becoming more important. This is especially true when a pilot has to receive signals from a low-power runway-localizing beacon while he is in the immediate vicinity of a strong airway beacon or weather station. To meet these stringent selectivity requirements Bell Laboratories has designed the 14A radio receiver. With the 12A receiver*, designed for telephone communication between airplane and ground, it provides for aircraft complete radio-receiver equipment of the highest quality and dependability. The 14A covers the frequency band from 200 to 400 kilocycles—which is the band assigned for beacon and weather stations—and the several improvements incorporated in it mark this receiver as a distinct advance over existing equipment.

The high selectivity obtained is shown by the curve of Figure 1. A signal separated only six kilocycles from the desired signal is attenuated 55 db. Although the sides of this curve are extremely steep, the transmission band is sufficiently wide to provide good intelligibility when weather broadcasts are being received. Moreover the high frequency-stability of the receiver, combined with the fairly wide band width, permit the use of a mechanical station selector. The gain obtained is so high that circuit noise is the limiting factor of the sensitivity of the receiver, and sufficient voltage step-up is provided in the antenna circuit to allow signals that impress as little as one microvolt on the antenna to be used. An automatic volume-control circuit is employed, which operates on the carrier and automatically adjusts the sensitivity of the receiver so that the output remains virtually constant regardless of the received signal strength.

A simplified schematic diagram of the receiver is shown in Figure 2. To obtain the required overall gain and selectivity a superheterodyne type of circuit is employed. The receiver contains a stage of radio-frequency amplification, a converter stage which combines the functions of oscillator and modulator in one tube, two stages of intermediate-frequency amplification, separate diodes for detection and automatic volume control, and two stages of audio-frequency amplification. The two diode elements and the triode used in the first stage of audio-frequency amplification are contained in a single tube. The appearance of the receiver is shown in the photograph at the head of this article and on page 268.

The radio-frequency and intermediate-frequency amplifier tubes are pentodes, the detector is a duplex diode-triode, and the output tube is a pentode capable of delivering approximately 600 milliwatts of audio-frequency power to a low-impedance headset. These tubes have heater elements designed to operate at ten volts, and thus all the tubes may be

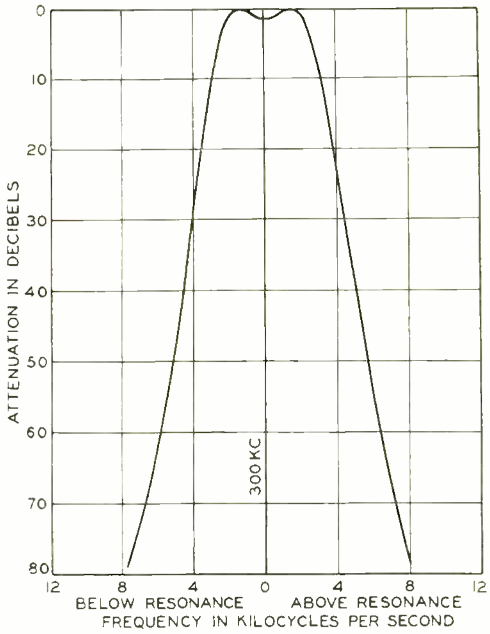


Fig. 1—Selectivity characteristic of the 14A radio receiver

*Record, *May*, 1933, *p.* 273

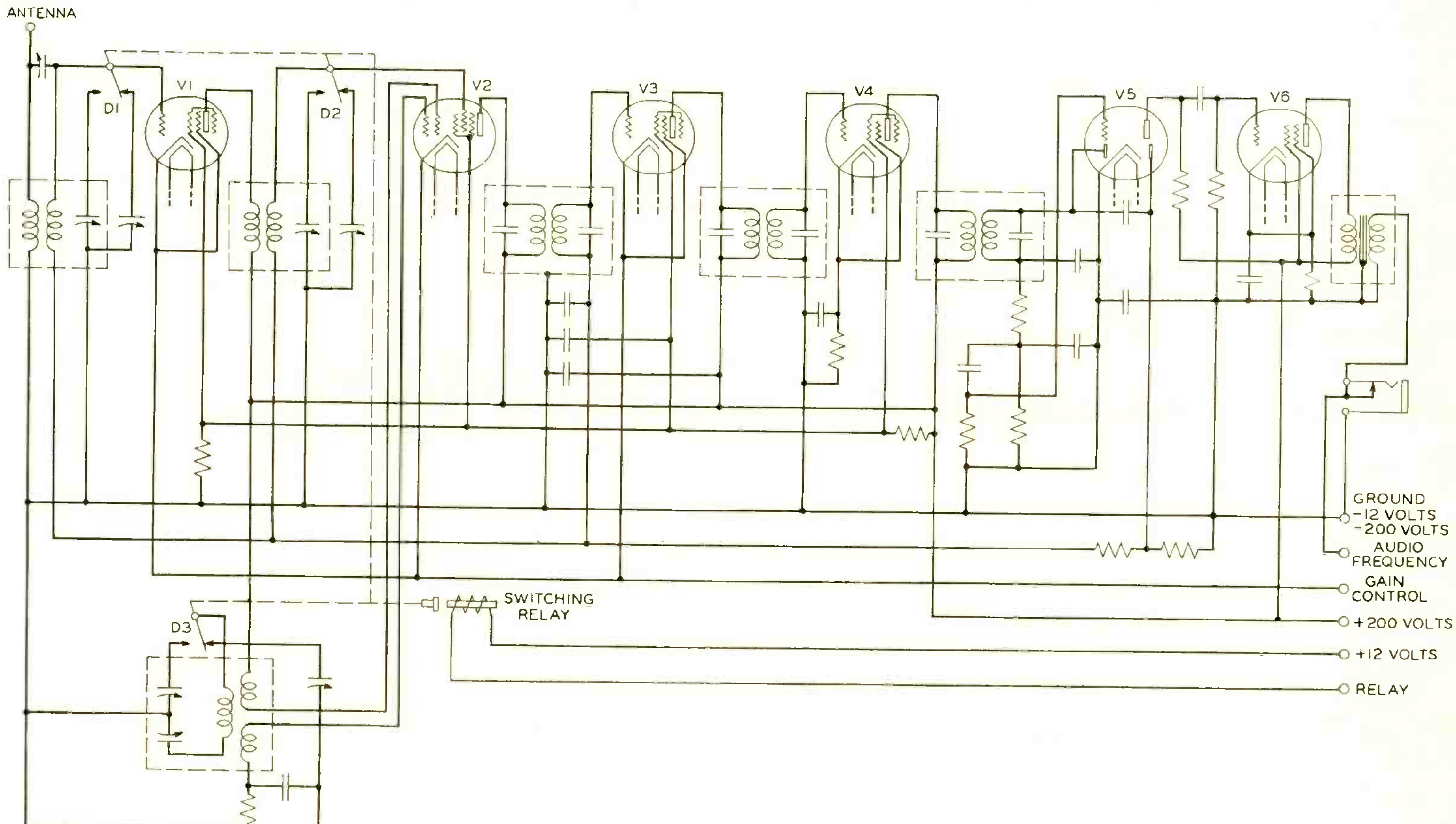


Fig. 2—Simplified schematic of 14A radio receiver

operated in parallel from a 12-volt battery. A ballast lamp is used in series with the heaters and provides adequate regulation for variations in heater supply voltage from 11.5 to 14.5 volts. The total current required for the heaters is 1.9 amperes, while the plate circuit drain is approximately 40 milliamperes at 200 volts. A small dynamotor operated from the 12-volt battery furnishes this plate supply.

To allow weak signals to be received with a good signal-to-noise ratio, the step-up from the antenna to the grid of the first tube has been made high as already noted. In addition the antenna circuit had to be designed so that comparatively large changes in antenna capacity would not seriously affect its tuning. The antennas used for beacon reception are practically pure capacity with a very low resistance. During bad weather, when the operation of the receiver becomes doubly important, the antenna may become covered with a thick coating of ice which greatly increases the capacity. With the antenna circuit of the 14A receiver, the antenna capacity may be increased to several times its original value without seriously affecting the step-up between the antenna and the grid of the radio-frequency tube.

Since the radio equipment on an airplane is usually located at some distance from the pilot who operates it, the 14A receiver has been designed for remote control. Tuning may be accomplished either by a mechanical drive coupled to the receiver by a flexible shaft, or by the motor-driven tuning mechanism described in an accompanying article.* Either of these controls selects any of the particular beacon frequencies that may be desired. In addition to these, however, the frequency of 224 kilocycles has been assigned for the operation of low-power airport transmitters. A fixed frequency channel has been provided in the receiver for the reception of these airport transmitters. It is not selected by the regular control but by a single switch located in one of the control units. This enables the pilot to shift easily and quickly from the main airway beacon to the local transmitter or vice versa.

To protect the receiver from the vibrations normally encountered, a shock proof mounting has been designed for installing the receiver in an airplane. A plug on the receiver engages a jack on the mounting and makes all necessary electrical connections as soon as the receiver is fastened in place. This arrangement permits the receiver to be quickly removed from the airplane for routine inspections which are made at frequent intervals.

**On the following page of this issue*

Remote Tuning Controls For Aircraft Radio Receivers

By B. O. BROWNE
Radio Development

WHEN commercial air lines began to operate over regular routes, a need was felt for some kind of guiding beacon to enable planes to fly a straight course in foggy weather when it was impossible to identify land marks. To meet this need the Department of Commerce set up series of radio beacons, approximately two hundred miles apart, on the various air lines of the country.

The radio receivers, employed to pick up these beacon signals, were at first mounted in the pilot's cockpit where they would be accessible for tuning and other adjustments. This method was soon found to be very unsatisfactory because the space available in the cockpits of most airplanes at that time was rather limited. It was soon evident, therefore, that a remote-controlled radio receiver would be much more desirable.

To meet this situation, Bell Telephone Laboratories designed a system using a flexible shaft to couple a tuning control, mounted in the pilot's cockpit, to the radio receiver, which could be mounted in the tail or other convenient part of the airplane. This system proved very satisfactory until large high-speed airplanes, capable of transcontinental flights, came into use. Since the radio beacons are only two hundred miles apart, and are operated on sixteen different frequencies to avoid interference between them, these long flights would require retuning at very short intervals. The operator would have to know not only the frequency of the beacon he was to follow, but its location on the tuning dial of the receiver. Moreover the new airplane radio receivers have a high degree of selectivity to enable them to separate the many closely spaced channels of the present time, and this requires that the tuning be done very accurately. Since the radio equipment must be operated by the pilot or co-pilot along with his other numerous duties, this type of control also has become unsatisfactory. The most desirable form of control seemed one that could select a number of predetermined positions of the tuning dial by push-button or dial manipulation at the pilot's position.

A control of this type, capable of selecting six or eight positions, has been in use with certain broadcast receivers, but it is much too bulky and heavy for use on airplanes. It was obvious that a distinctly new type of control would have to be developed Many methods were discussed and certain of the most promising were built and tested. As a result of this preliminary work a control system has now been developed, known as the 700A selector, which combines lightness and dependability with a large number of selective positions. It is designed to mount on the front of the 14A receiver* with six screws, and may be operated from the pilot's position by either of two types of control unit.

A simplified schematic diagram of the new selector is shown in Figure 1. A worm-wheel is coupled to the shaft of the tuning condensers of the receiver and is rotated through a

Described on p. 264 of this issue.

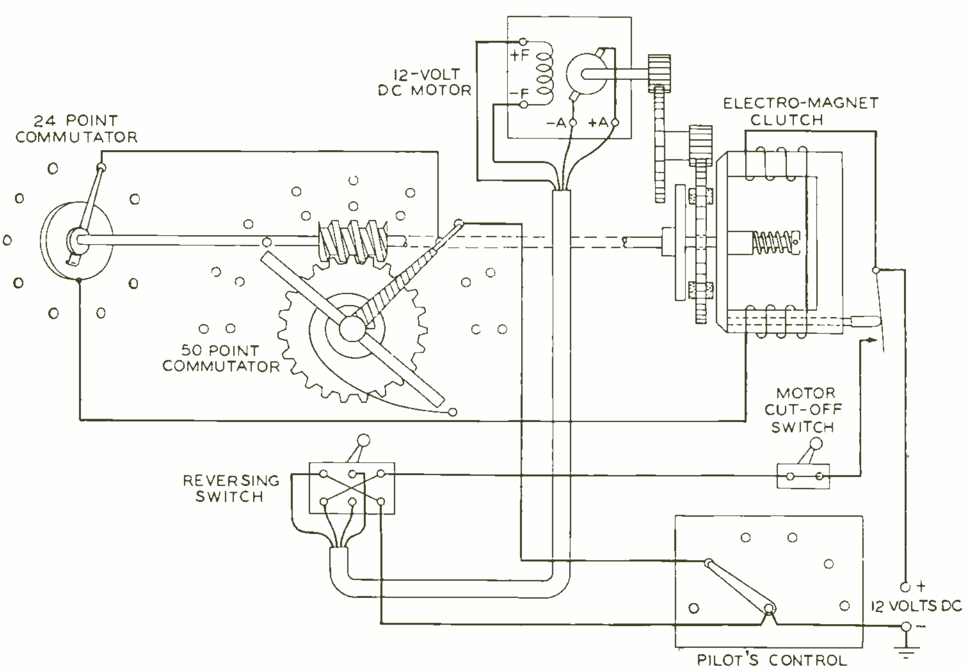


Fig. 1—Diagrammatic arrangement of selector showing the two commutators and the method of interconnecting

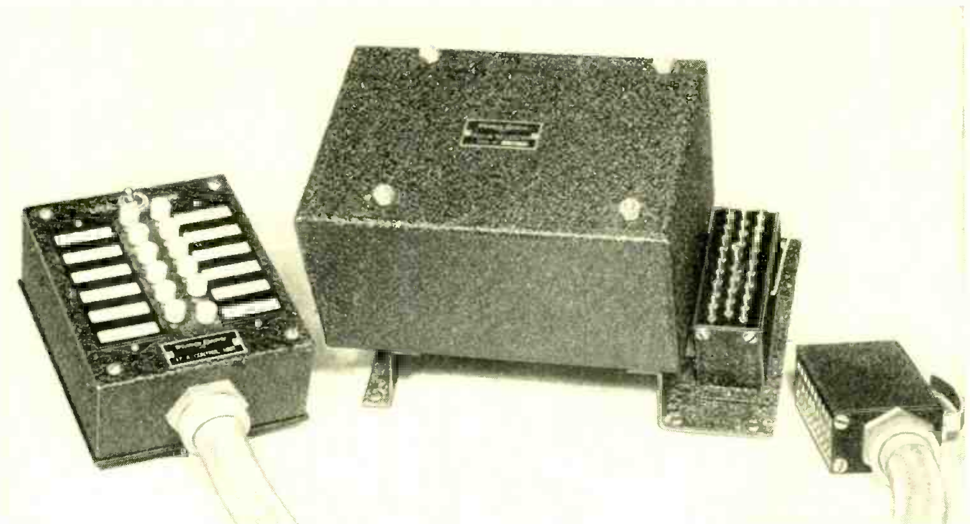


Fig. 2—The selector is mounted within an enclosing metal cover and carries a 28-contact receptacle for the cable running to the pilot's position

worm driven by a small motor operated off the 12-volt battery of the plane. The position at which this worm-wheel, and thus the tuning condensers, stop is controlled by two commutators at the selector and a control switch at the pilot's position. The scheme provides for stopping the tuning condenser at any one of 600 equally spaced positions around its complete 180° arc of motion. When the proper position is reached, the drive is stopped by the release of a magnetic clutch. As the clutch releases, it applies a brake to the drive shaft and at the same time opens the circuit to the motor.

The two commutators and the control switch, together with typical interconnections between them which determine the stopping position, are shown schematically in the illustration, although to avoid crowding the drawing only a part of the total number of segments on the commutators are shown. One commutator has fifty pairs of segments and the brushes sliding over them move with the worm-wheel connected to the tuning condenser. The two brushes of this commutator are connected together so as to cross connect one pair of segments in each position. The size of segments and brushes are so proportioned that the brushes are always in contact with a pair of segments.

Segments of the second, or 24-point, commutator are located around the complete circle, and the brush sliding over them is driven by the worm-shaft. The reduction ratio between the speed of the worm and the worm-wheel that drives the brushes of the 50-point commutator is such that the brush of the 24-point commutator makes one complete revolution while that of the 50-point commutator travels over two segments. Connections are made from segments of the 24-point commutator to the inner segments of the 50-point contact, and from the outer segments of the latter to points on the control switch at the pilot's station. Negative battery is connected to the arm of the control switch and positive battery to the clutch, while a connection from the other end of the clutch winding to the brush arm of the 24-point commutator completes the circuit.

The action of the selector may be readily understood by following through the process of setting up a position after the selector has been attached to the radio receiver. A small knob, attached to the free end of the worm-shaft, enables the tuning condensers to be turned by hand. The first step is to turn this knob until the desired beacon station is properly tuned in. A connection is then made between the point on the control dial that is to be used for selecting this station to the outer segment of the 50-point commutator on which the brush is now resting. A second connection is then made from the inner segment of this position of the 50-point commutator to the segment of the 24-point commutator where its brush is resting. If battery is now connected, the clutch will at once operate to lock the worm-shaft in its present position, and the circuit to the motor will be opened.

If the control switch at the pilot's position is now moved, the circuit through the clutch and the two commutators is broken, the clutch will release, the motor circuit be closed, and the motor will drive the selector until another set of similarly established connections closes the circuit and operates the clutch. The worm-wheel carries a cam which operates a switch to reverse the motor when the worm-wheel has been rotated to either one of its extreme positions.

Since it is imperative that the tuning condensers always stop at exactly the same position for any one setting of the control switch, no backlash between the worm and worm-wheel can be allowed. Regardless of the direction in which the worm-wheel is being moved, the same side of the teeth of the wheel should always be in contact with the worm. This is brought about by a spiral spring, like the mainspring of a clock, which always tends to rotate the worm wheel in one direction. Thus for rotation in one direction the motor drives the worm-wheel against the action of the spring, and in the other direction the spring drives the worm-wheel and tuning condenser—the motor-driven worm merely acting as a release mechanism to control the rate of motion and the stopping position of the commutator.

The appearance of the selector is shown in Figure 2 and, with cover re-

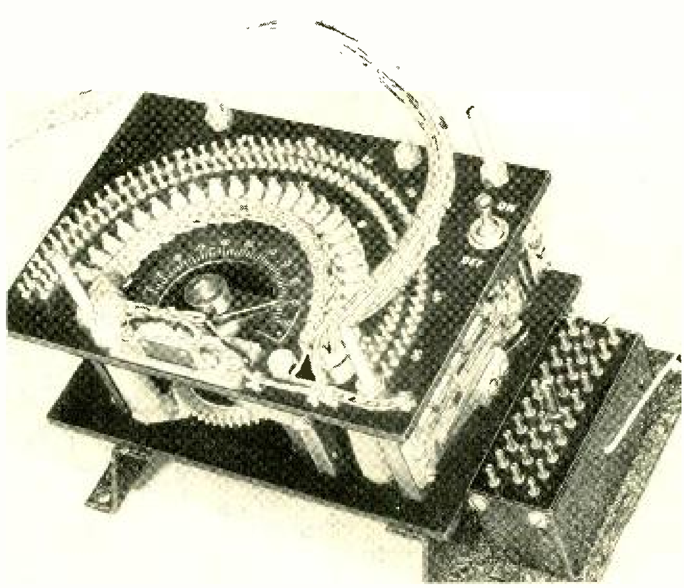


Fig. 3—When the cover is removed, the terminals of the segments of both commutators are readily accessible

moved, in Figure 3. At the right of the former illustration is a 28-contact jack and plug used for connecting a 28-wire cable from the pilot's position to the selector. The terminals for both the commutators are brought to the front of the front panel of the selector so that the connections for setting up the various stations may readily be made, as is shown being done in the frontispiece to this issue of the RECORD. This photograph also shows the push-button type of control switch which may be installed at the pilot's position. The dial-type switch is shown in the photograph which appears at the head of this article.

Since the number of stations that must be tuned-in will vary, two types of control stations have been provided. One, with twelve positions, consists of a bank of twelve interlocking push-button keys mounted in a protective housing. A unit of this type with 24 positions would be too large for airplane use, and so a 24-position dial switch was developed for use where more than twelve positions are required. The new system thus provides a very simple tuning procedure. The pilot merely has to push a button or turn a dial to the desired position—the rest is done for him automatically and quickly.

Articulation Testing

By W. A. MUNSON
Acoustical Research

AN articulation test, as the name implies, determines how well a telephone system reproduces each of the many separate sounds of which speech is composed. The fundamental speech sounds vary somewhat in different languages and dialects. In fact, even in the speech of one particular person the pronunciation of a sound may vary considerably depending upon how it is combined with other sounds and the emotional emphasis of the speaker. Articulation tests made in this country use only those sounds which occur in the speech of the majority of the people, and the tests are further simplified by limiting the pronunciation to a conversational tone of voice.

The general features of making an articulation test are not difficult to imagine. A caller pronounces the speech sounds into the telephone which it is desired to test and an observer listening at the receiving end writes down his interpretation of what he hears. In order that the effect of combination with other sounds may be included in the test, the sounds are grouped into syllables composed of an initial consonant, a vowel, and a final consonant. In addition to this, the syllable is spoken as part of a sentence of set form which serves to make the test more comparable to conversation, but only the test syllable is written down by the observer. A list of the speech sounds used in articulation syllables and key words which illustrate their pronunciation are shown in Table I. Figure 1 illustrates how they are combined to form articulation testing syllables.

TABLE I

Speech Sounds For Testing Lists

Initial Consonant	Key Word	Vowel	Key Word	Final Consonant
b		a	father	b
d				d
f		ā	fame	f
g	go			g
k		a'	fat	k
l				l
m		e	get	m
n				n
r		ē	greet	r
p				p
s		i	tin	s
sh	ship			sh
th'	this	o	but	th'
th	thin			th
t		ō	go	t
v				v
ch	church	u	full	ch
z				z
j	judge	ū	rule	j
h				zh
w		o'	haul	ng
y	yawl			st

Since it is desirable to have natural combinations of sounds the reader may well ask why complete words are not used instead of just syllables. In certain types of tests where the observer is not familiar with the phonetic alphabet, complete words are used, but this introduces a very important factor, namely, the thought or meaning conveyed by the word. Obviously an observer may hear only part of the sounds of which a word is composed and yet his familiarity with the word may enable him to distinguish it quite definitely. To avoid this the meaningless syllable is used.

The recording sheet of a typical articulation test is shown in Figure 1. The syllables are written down in the "observed" column and afterwards compared with those called. In the case of this caller and observer, the syllable articulation of the telephone circuit tested was 51.5. By articulation is meant the percentage of sounds or syllables correctly perceived. Of course, a single test will not give a result typical of a large number of persons and ordinarily fifty or more different caller-observer pairs are used to obtain average results. Automatic apparatus for recording and tabulating errors has been developed for reducing the labor of such tests.

Figure 2 shows a detailed analysis of the results of 56 tests of the type shown in Figure 1 using both men and women callers and observers. Here the average syllable articulation has been computed and also the articulation of each individual sound. Even with this large number of tests the probable error of the syllable articulation is approximately ±2 and ±5 for the separate sounds. The accuracy attained is not very great because of the many physiological and psychological factors which complicate and obscure the effect of the telephone system upon the results.

The number of sounds which an observer interprets correctly depends greatly upon his alertness and ability to concentrate on the test. For this reason different observers and also the same observer at different times may obtain widely varying articulation results depending upon their mental attitude at the time the test is taken. A large number of tests with many different

ARTICULATION TEST RECORD

DATE 3-16-28 SYLLABLE ARTICULATION 51.5 %

TITLE OF TEST Practice Tests CONDITION TESTED A

TEST NO. 10 OBSERVER W. H S Jr

LIST NO. 5-9-37 CALLER E. B

NO.		OBSERVED	CALLED	OBSERVED	CALLED	OBSERVED	CALLED
1	THE FIRST GROUP IS	maʹv ✓	maʹv	poʹz	poʹth	kōb ✓	kōb
2	CAN YOU HEAR	pōch ✓	pōch	nēz	nēzh	shēth	siz
3	I WILL NOW SAY	seng ✓	seng	joʹch ✓	joʹch	fūch ✓	fūch
4	AS THE FOURTH WRITE	chūd ✓	chūd	thaʹm ✓	thaʹm	thōl ✓	thōl
5	WRITE DOWN	run ✓	run	hab ✓	hab	poth ✓	poth
6	DID YOU UNDERSTAND	chiz	kiz	def	doth	waʹm ✓	waʹm
7	I CONTINUE WITH	foz	fozh	chech	chej	gūm	gūn
8	THESE SOUNDS ARE	loʹl ✓	loʹl	lun	lon	nāsh	nāth
9	TRY THE COMBINATION	jās	zhāth	shāl ✓	shāl	voʹg ✓	voʹg
10	PLEASE RECORD	thaʹth	thaʹsh	muz ✓	muz	lung	long
11	WRITE THE FOLLOWING	wūr ✓	wūr	lēd	bēd	diz	dizh
12	NOW TRY	yāp ✓	yāp	wif ✓	wif	kak	tak
13	THIRTEEN WILL BE	mad	maj	gōst ✓	gōst	thaʹr	zhaʹr
14	YOU SHOULD OBSERVE	bēch	bēk	thār	sav	must ✓	must
15	WRITE CLEARLY	gēm	dēm	kōf ✓	kōf	yoʹd ✓	yoʹd
16	NUMBER 16 IS	theb	veb	raʹg ✓	raʹg	jet ✓	jet
17	YOU MAY PERCEIVE	jok	jost	thip ✓	thip	rēp	rēj
18	I AM ABOUT TO SAY	gaf ✓	gaf	yar ✓	yar	thēp	hēp
19	TRY TO HEAR	hus ✓	hus	zhūt ✓	zhūt	-------	chu ✓
20	PLEASE WRITE	hir	thith	kūk	tūk	thef	thesh
21	LISTEN CAREFULLY TO	tōg ✓	tōg	fung	fung	bās ✓	bās
22	THE LAST GROUP IS	shoʹt ✓	shoʹt	thʹev	vesh	thoʹf	shaf

Fig. 1—While caller EB said "The first group is náv, Can you hear pŏch" and so on, observer WHS wrote down here what he heard. Later the syllables called were added for comparison

ARTICULATION TEST ANALYSIS RECORD

BELL TELEPHONE LABORATORIES

INCORPORATED

DATE 2-29-28 to 3-21-28 TITLE Practice Tests

REFERENCE MM-2186 8-27-28 CONDITION A

OBSERVERS EB, WHS, FS, CM, HC, AH, ELF, LW LETTER ARTICULATION 79.3 SYLLABLE ARTICULATION 51.6

LETTER	OCCUR. PER CALLER	ERRORS PER CALLER											Ind. Sound Art.
		EB	WHS	FS	CM	HC	AH	ELF	MW	Total Errors	Total Occur.		
a	42	3	2	10	1	15	2	2	3	38	336		88.7
ā	42	1	1	4	0	7	2	0	2	17	336		94.9
TOTAL	462	29	11	61	21	98	70	68	50	408	3696		89.0
b	42	7	0	11	10	13	1	4	6	52	336		84.5
ch	42	13	4	11	13	2	8	8	7	66	336		80.4
TOTAL	924	263	167	236	242	256	248	243	236	1890	7392		74.4

E-1545 A (6-28)

Fig. 2—While caller EB went through the list of syllables in Figure 1, all the other members of the crew listened with head receivers. The figures 3, 1, 2, etc. in the fourth column indicate the total errors made by all listeners during that test. Each vowel occurred six times in the list; with eight successive callers and seven observers each time, the vowel a occurred 336 times as indicated under "Total Occur." The final column shows the percentage of correct observations. "Letter articulation" is a grand total average for all sounds; and "syllable articulation" is a similar figure for correct perception of entire syllables

observers decreases the importance of this difficulty.

Another source of error exists in the element of skill which is inherent in an articulation test. That is, the proficiency of an observer will increase as he becomes familiar with the caller's voice and the effect of the telephone system upon his voice. Changes in the skill of observers become important when the tests extend over a long period of time, but this can usually be detected by making reference tests on a control circuit always having the same characteristics.

Having completed an articulation test on a telephone system, the results will show which of the speech sounds are conveyed clearly from the speaker to the listener and the degree to which the intelligibility of others is impaired. Since the physical characteristics of the circuit are known, it is possible to use this particular test along with others to derive a correlation between articulation and such factors as loudness, frequency range, modulation, and noise. This procedure, or modifications of it, is applied to new developments which affect intelligibility, although in some cases the accumulated data enables the results to be predicted from measurements of the physical characteristics of a system.

Automatic Articulation Testing Apparatus

By L. Y. LACY
Transmission Research

An extensive program of applying articulation tests to a considerable number of different circuit conditions often requires the entire time of a testing crew composed of from eight to ten people for a period of several months. Such programs have emphasized the importance of reducing the time required to obtain results of a given precision. In adapting the tests developed in the Acoustical Research group* for large-scale use in transmission research, it was felt that the compilation of written lists, the hand recording of syllables by each listener, and the checking and counting of errors should be replaced by electrical methods for the recording and analysis of data.

There have been two systems of automatic analyzing equipment developed; the first was constructed in 1930 and used until the early part of 1933, and the present system, having a large number of improvements, has been in use since that time.

The operating principles of the machine now in use are as follows. From each of a large number of syllable lists, a teletype tape is perforated. When one of these tapes is passed through a standard teletype transmitter, the electrical impulses cause three lamps to light behind a translucent screen. Two of these lamps illuminate consonants and one a vowel, as shown in Fig. 1. The caller, viewing the screen, then repeats into the microphone one of the "carrier" sentences shown above the screen, with the indicated syllable inserted thus: "When will nud be

*See page 273 of this issue.

done." A commutator, after allowing an interval for this to take place, advances the tape through the transmitter and another syllable is displayed.

Fig. 2—Each observer presses keys corresponding to the three sounds of the syllable as she understands them

Four observers listen simultaneously to the sounds as transmitted by the system under test. Before each one is a bank of plunger-type keys, each key designated by one of the sounds in the English language. Each observer presses three keys to represent his (or her) perception of the three sounds in the test syllable. The keyboards are so interconnected with the teletype transmitter that a relay is operated for each key correctly pressed. The timing commutator also controls a standard teletype page printer through the relays which were left unoperated by the observers, to print the number of errors made on each of the three sounds in the syllable called, and operates counting circuits to store the total number of errors made by each observer which are printed after 66 syllables have been called and observed.

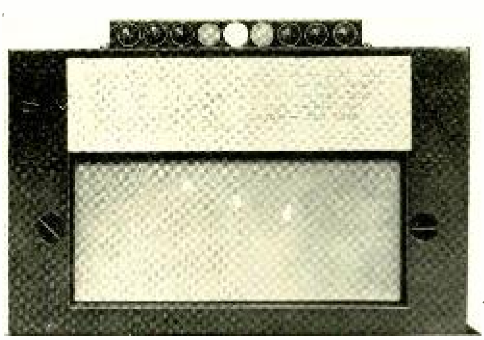


Fig. 1—The caller regulates the level at which he calls the syllable appearing on the visual indicator according to the signal given by the automatic volume indicator lights

A typical record is shown in Fig. 3. In the first four lines each group of three digits shows the number of errors made on that syllable. The first digit gives the number of errors made on the initial consonant; the second, the vowel errors; and the third, the number of errors made in the final consonant of the syllable. For example, the first number—100—shows that some observer made an error in the initial consonant of the first syllable called and that no errors were made in the vowel or final consonant.

The fifth line of the record gives the following information: (MCD), the caller's initials; (450), the list number; "B", the condition tested; (18), the serial number of the test; next "1-50" shows observer One made 50 errors. Similarly observer Two made 50 errors, observer Three 60 errors, and observer Four 46 errors. The transmitter number is T3, N46.0 the noise level on the circuit under test, S70.1 the speech level on the circuit expressed in decibels above an arbitrary reference point.

Equipment which records the test data in this way and which also analyzes it has reduced the time required to complete a program of articulation tests by almost one-half. In a single test eight callers each call a list of 66 syllables to four observers. Since each syllable contains three sounds a total of $8 \times 66 \times 4 \times 3 = 6336$ sounds must be compared to those called and all errors noted. When written records of the syllables are made, the data must be analyzed by the crew. By this method one test comparing two circuit conditions is about all that can be completed daily due to the time required for data analysis. In a short series of tests this rate may be exceeded somewhat but for a large number of tests the figure given is representative. When the automatic equipment is used, however, the data is analyzed by the machine as the test progresses. Twice the amount of data can be obtained with the added advantage that the analysis is done by a mechanical process which is not subject to human error.

While the automatic data analysis has reduced the testing time, additional refinements have been made to improve the precision of the results. In a series of articulation tests it is desirable to control or eliminate as many variables from the test conditions as possible. One variable which is of major importance is the intensity with which a caller speaks the test sentences and syllables into the transmitters of the circuit under test. Even though it is possible for a caller to maintain a constant level for a single list, it is unlikely that the seven other callers will speak at that same intensity and even less likely that the desired level will be maintained from day to day. Measurement and control of electrical intensities in the circuits directly under test have given unsatisfactory results, primarily because of the difficulty which arises when an attempt is made to specify or compare speech intensities on two circuits having different frequency characteristics. This difficulty has been overcome by the addition of a "caller's control circuit".

Instead of speaking directly into the carbon-button transmitters of the test circuit the caller speaks into a high-quality transmitter. The output of this transmitter is amplified before passing into the artificial mouths* which are placed in front of the test transmitters. The overall response of the caller's control circuit has been equalized to give a faithful reproduction of the caller's voice. The out-

*Record, *November*, 1933, *p.* 85.

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100-310-321-111-300-401-042-111-201-112-410-010-300-000-001-110-401-000-
303-311-000-010-200-100-003-113-200-103-001-101-320-001-102-303-013-402-
302-003-001-102-102-400-001-01[illegible]-304-110-112-101-200-130-000-310-202-103-
301-301-411-000-002-001-201-211-104-001-402-011-
MCO 450 818-1 50-2-5[illegible]-3-60-4-46 T3 N46.0 S70.1
```

Fig. 3—A complete record of the articulation test data is made by the page printer

put level of the artificial mouth is controlled by the caller who raises or lowers his calling level depending on what he is signalled to do by the nine signal lights on the visual syllable indicator, Fig. 1. The signal lights are operated from an automatic volume indicator which has its input bridged across the output of the high-quality transmitter amplifier. At the beginning of a list the center indicator lamp is lighted and remains so as long as the caller maintains the desired calling level for which the system is calibrated. If the caller lowers his calling level by 2 db, however, the illumination will continually move to the left, one light for each sentence called low. If he raises his level back to the correct value the position of the lighted lamp will remain unchanged and one of the lower level lamps will remain illuminated until he raises his level above the calibrated value so as to bring his average calling level for the sentences called thus far back to the correct value, at which time the illumination will move back towards the center light. Thus a change in the position of the light shows the departure of a particular sentence from the desired level while the position itself shows the sum of the departures.

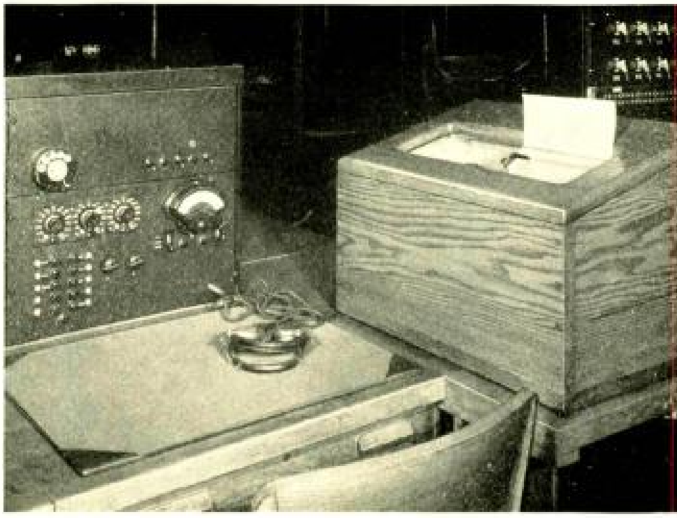


Fig. 4—The control panel, shown at the left, permits the engineer in charge to check the circuit conditions easily and quickly

The transmitter changer and agitator is another valuable piece of automatic equipment which has been added to speed up testing. Since differences exist in the characteristics of shop-product commercial transmitters a number of them are used to reduce the effects of their inherent differences on test results. The transmitters in the circuit under test are changed once for each caller. Five transmitters are mounted on a motor-driven disc (Fig. 5). The selection of the transmitter to be used for each caller is made from a dial located on the control panel outside of the booth. The selected transmitter is rotated for at least one revolution of the disc to give it the proper agitation and then it is automatically centered in front of the artificial mouth.

Typical line and room noises are obtained from phonograph records. Two turntables and reproducers are used in a test, one for the line noise and another for room noise. The reproducers are automatically set down on the record at the beginning of a list under the control of the data recorder and analyzer, and are lifted from the record at the end and returned to the starting position.

The control panel shown in Fig. 4 at the left is used to change test conditions and check various circuits. A

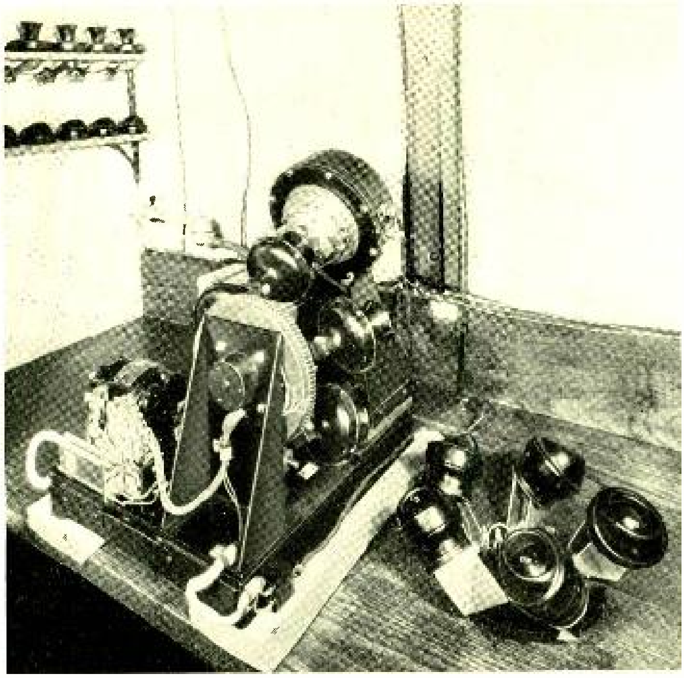


Fig. 5—The transmitters used in testing are mounted on a motor driven disc which is under the control of a dial on the control panel. This apparatus serves to agitate the transmitters in a uniform way and then center them properly in front of the artificial mouth

master switch located on this panel permits the selection of either of two test conditions which have been previously set up by another set of keys used to select individual circuit elements. At the beginning of each list the volume indicator on the control panel is used to check rapidly the circuit equivalent and the magnitude of the line and room noises. Any undesired changes in the test conditions can be detected readily and corrected before a large amount of data has been taken on an improperly adjusted set of test conditions.

Automatic speech and noise measurements are made on the circuits under test and average values are recorded on the data sheet by the teletypewriter. The apparatus for these measurements is similar to the automatic volume indicator used in the caller's control circuit except that a mechanical averaging circuit is used instead of a visual indicator.

The first automatic data analyzer used, which was mentioned in the early part of this article, although not in use now had quite an interesting feature. The lists were made up automatically as needed instead of being prepared in advance as they now are for the present machine. A system of relays and selectors was arranged so that the order in which the 22 initial consonants, 11 vowels and 22 final consonants were presented to the caller was varied mechanically in a random manner. Each list was censored automatically for undesirable combinations of sounds, the need for which is evident. Certain combinations of the test sounds must be eliminated as they are difficult to pronounce properly, others because of their undesirable English meaning. When undesirable combinations were found the order was rearranged automatically and censored again until a perfect list was formed. This total preparation of a sixty-six syllable list took an average time of only six seconds.

Adapting The Telephone Repeater To Train Dispatching

By H. D. KELSO
Equipment Development

TO keep trains moving safely and on schedule, railroads of the United States divide their lines into sections. To each of these sections is assigned a dispatcher who, located at some convenient point, is responsible for the movement of all traffic over his section. It is, of course, of prime importance that he be able to communicate with any station of his section. At the present time the telephone is quite generally used for this purpose, and since the sections are not ordinarily very long, repeaters have not usually been required. Recent operating changes, however, have resulted in lengthening some of the telephone dispatching circuits to a point where amplification is necessary.

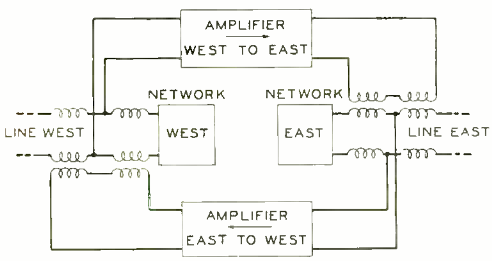


Fig. 1—Simplified circuit layout at a two-wire repeater station

As these circuits are in many respects similar to toll lines the 22A1 telephone repeater, which is standard for the telephone plant, was chosen as the basic amplifier in the assembly designed for this service. This repeater has already been described in the Record.* It is of the two wire, two way type—conversation in both directions being conducted over the same pair of wires. The complete repeater arranged for railroad dispatch service is shown in Figure 2. The assembly consists of three panels—a power supply panel, a by-pass and switching panel, and a 22A1 telephone repeater panel all assembled as a unit within a steel cabinet.

The repeaters will usually be located in railroad offices, stations, or switch

*Record, *August*, 1931, *p*. 579.

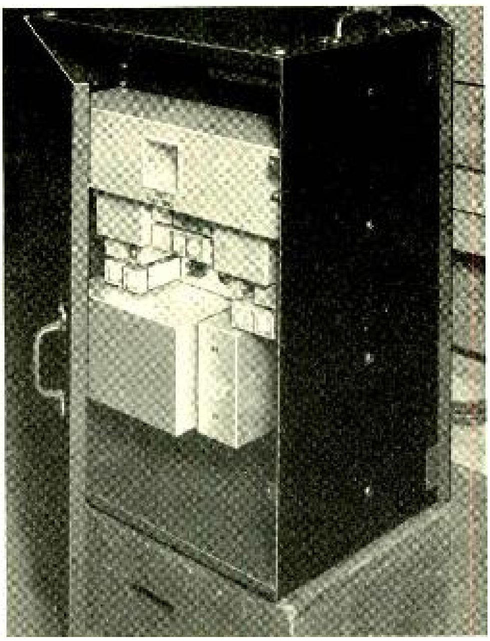


Fig. 2—The train-dispatching repeater is mounted in a self supporting metal cabinet with doors on the front and back

towers where no battery supply is usually available. In view of this and the fact that only one or two repeaters would usually be provided at any one point, it was felt desirable to include rectifying equipment operating from a commercial 110-volt 60-cycle supply. The power-supply panel furnished utilizes a full-wave vacuum-tube rectifier. Rectified and filtered grid and plate potentials are supplied to the repeater through this tube while unrectified alternating current stepped down to the proper potential is furnished to heat the filaments. A heavy metal cover fits over this panel and encloses everything on it except the rectifier tube. A well is built into the front of the cover which gives access to this tube when the cover is in place. The 110-volt supply is connected to a flush receptacle on the back of the panel by means of a cord and attachment plug, while another flush receptacle and a multi-conductor cord and plug are used to connect the power supply to the repeater. This arrangment has the advantage of permitting the power supply panel to be readily used in other applications where the current drain and voltage conditions are suitable.

The line in each direction from the repeater is balanced in an arrangement of resistances and condensers known as a balancing network. These networks are shown schematically in Figure 1, and in more detail in Figure 3. The degree of balance between the impedance of the line and network determines to a large extent the maximum usable gain of the repeater. With a good balance the amplification may be high while if it is imperfect, the amplification must be reduced. Because of the non-uniformity of railroad dispatch circuits, due largely to the presence of bridged subsets, networks

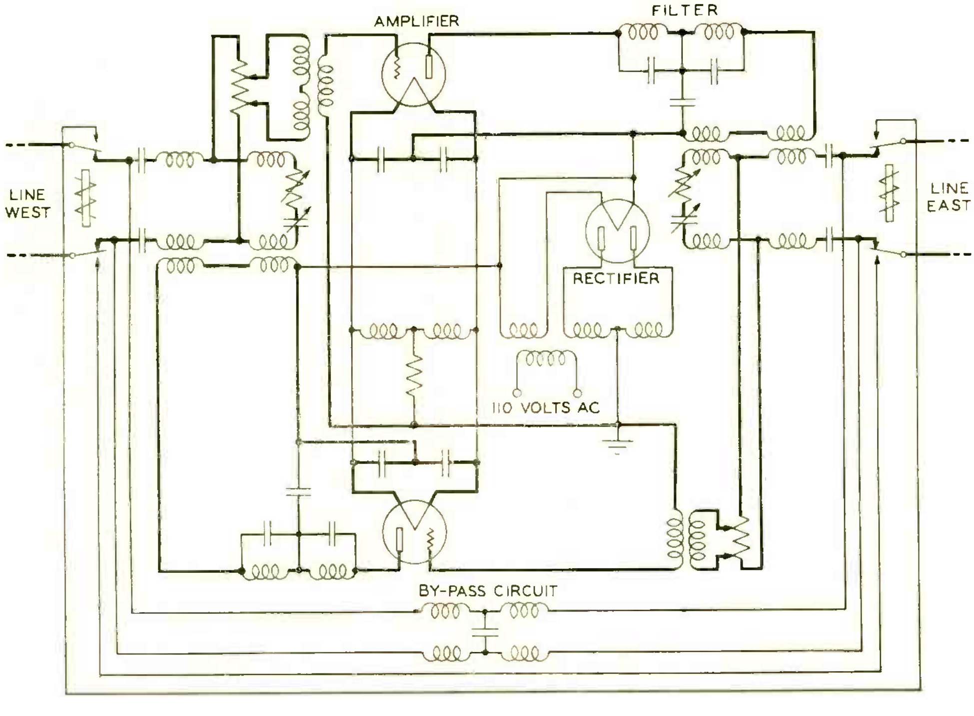


Fig. 3—Simplified schematic of the dispatching repeater circuit

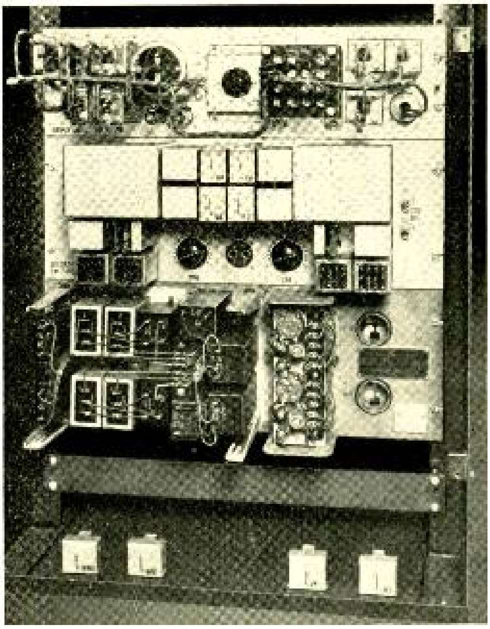


Fig. 4—The networks are adjusted by two dials for resistance variation and by changing taps on the proper condensers

composed of adjustable condensers and resistances are provided. Knobs for changing the value of the resistance are mounted on the front of the panel, while the capacitance is changed by taps under the covers of the condensers. These networks provide means for approximately balancing any one of a number of different types of lines. The equipment for these networks, together with the equipment for a signal by-pass and a cut-out circuit, is mounted on a panel directly above the repeater. The by-pass circuit provides a path around the repeater for signalling and telegraph currents, while the emergency shunt circuit, connected through relays, disconnects the repeater and cuts the line straight through if the flow of plate current ceases. Thus a failure of the power supply, or a burned-out tube will not result in totally disabling the circuit, since conversation may proceed without interruption, although the received volume may be lower than desirable. This feature as well as the by-passing arrangement is illustrated in Figure 3.

The three separate groups of apparatus—the 22A1 repeater, the power supply, and the balancing networks and switching equipment—are assembled as a unit within a simple metal cabinet. The unit will also mount upon the standard relay rack framework should this be desirable. The cabinet is of heavy gauge sheet steel with doors front and rear, and is lacquered in green to harmonize with other office furniture. Knockout holes are provided so that the line and power supply leads may be brought in either at the top or bottom. This cabinet secures great simplicity by being assembled from three pairs of parts, each part being a rectangular sheet of metal bent up at two edges. Up the middle of the two side pieces is fastened an angle iron drilled for

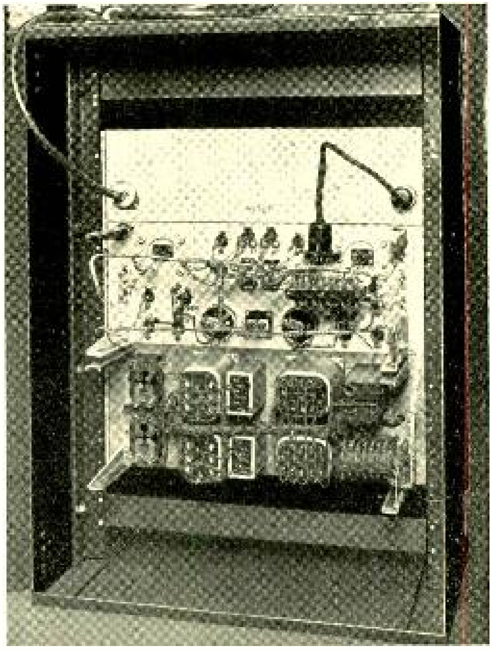
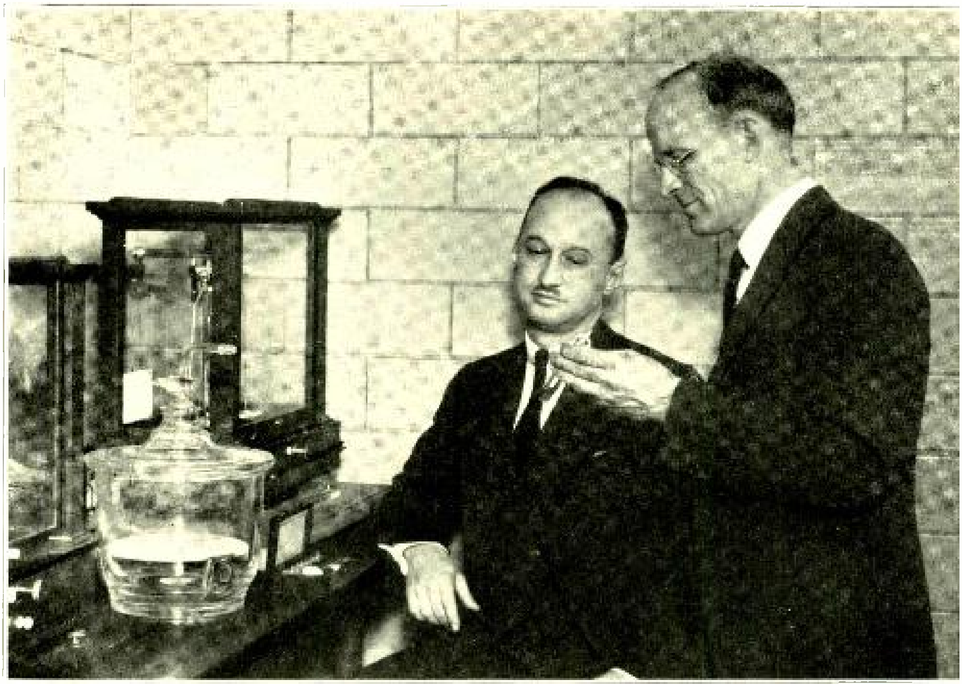


Fig. 5—Cords and plugs are used to connect the power panel to the supply and to the repeater

standard relay-rack mounting plates. The three panels of the complete repeater are fastened to these angles as shown in Figures 4 and 5.

Here the upper panel is the power supply with the rectifier tube mounted in a well in the center. Beneath that is the network and switching panel with monitoring jacks in the lower middle, and the knobs for network adjustment on each side. A front view with some of the covers removed is shown in Figure 4, and the rear side with cover removed is shown in Figure 5. Here at the left of the power supply panel may be seen the cord for connection to the lighting circuit, and at the right, the cord and plug to connect the rectified power supplies to the repeater. Connections between the center panel and the repeater beneath it are all made through the local cable connected to terminal strips on the two panels.

Although in its present form the repeater is intended primarily for railroad dispatch circuits, it may find a field of use in the telephone plant. It may also have some application on Bell System circuits where only small gains are required and the signaling arrangements permit. Development work is now under way on an assembly designed to meet the requirement for small installations of repeaters on toll circuits.



Vitamin B

When Robert R. Williams, Chemical Director of these Laboratories, worked as a chemist with the government laboratories in the Philippines, he helped to secure the evidence that some unknown chemical, present in infinitesimal quantities in rice bran, cured the oriental disease, beri-beri. Ever since, he has continued this work as an outside interest, more recently with the assistance of Robert E. Waterman of the Chemical group (shown with Mr. Williams in the photo above) and Marion Ammerman and J. C. Keresztesy of Columbia University. As a result of it, he was able to show those who attended the recent meeting of the Federation of American Societies of Experimental Biology several small vials containing white crystals of purified vitamin B. This was a portion of the five grams of the vitamin obtained from a ton of rice polishings.

Mr. Williams has prepared a far larger quantity of vitamin than had heretofore been prepared by any worker in this field, and the efficiency of its preparation was several times greater. It has been estimated that about twenty-five per cent of the vitamin originally present in the rice polishings has been obtained in pure form. The careful and arduous procedure by which this yield of the material is obtained has been standardized by Mr. Williams and his associates, and will now for the first time make it practicable to prepare the vitamin in pure form for medical use.

The method of extraction uses the mysterious force of adsorption. To a water extract of one ton of rice bran, eighty pounds of the mineral powder, fuller's earth, are added, and the particles of this material adsorb the molecules of the vitamin. To get these molecules loose again, quinine sulphate is added to a watery mixture of the vitaminized fuller's earth. The molecules of quinine knock off the vitamin molecules from the earth particles and take their place, so that the vitamin is left free in the solution, from which it is concentrated and crystallized by a long series of further steps.

So powerful is this crystallized vitamin in preventing or curing beri-beri and related nervous conditions either in men or in animals that the necessary doses are measured in micrograms, one microgram being about one thirty-millionth of an ounce. Even more remarkable results appear when rats or other laboratory animals are given diets containing excess doses of the purified vitamin, still only a few micrograms a day but several times larger than the quantities present in ordinary foods. Rats thus slightly over-fed with the vitamin grow much faster than ordinary rats fed a diet usually regarded as excellent, but having only normal amounts of this particular vitamin. There is evidence that the final size of adult animals may also be increased. Physicians are reported to be testing the effects of doses of the vitamin on cases of polyneuritis and mal-nutrition in human beings.

Contributors to This Issue

H. B. FISCHER received a B.S. degree in Electrical Engineering from the University of Wisconsin in 1924 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 receivers for mobile systems.

AFTER EIGHT YEARS' service in the power field, H. D. KELSO left the engineering department of the Central Illinois Public Service Company in 1920 to join the Equipment Engineering group of the Western Electric Company. At Hawthorne he was engaged chiefly in machine switching work until he came to the Laboratories in 1929. Here, with the Toll Equipment group, he has been employed for the most part on transmission testing equipment.

HAVING SPECIALIZED in physics at the Southern Branch of the University of California, from which he was graduated in 1927, W. A. MUNSON entered the Acoustical Research group of the Laboratories. At first he was concerned with articulation studies, the subject of his current article in the RECORD. During the last four years he has been principally engaged in investigations of the loudness of pure and complex tones.

ENTERING THE Laboratories immediately after graduation by the University of Illinois in 1929, L. Y. LACY joined the Wire Transmission Research group. Here he has assisted in the design and testing of the apparatus for articulation testing, and has individually contributed the circuits which he describes in this issue of the RECORD.

W. E. REICHLE received a B.S. degree in Electrical Engineering from the University of Michigan in 1928, and immediately joined the Technical Staff of Bell Laboratories. Here, with the Radio Development group, he has been engaged in the development of aircraft radio receivers for both beacon service and two-way communication.

AFTER NINE YEARS with the Crocker-Wheeler Company, B. O. BROWNE joined

H. B. Fischer

H. D. Kelso

W. A. Munson

L. Y. Lacy

W. E. Reichle

B. O. Browne

the Apparatus Drafting Department of these Laboratories in 1919. He transferred to the Radio Department group in 1924 where he has since been engaged in the mechanical design of aircraft and ground station receivers.