The Smallest, Cheapest LOUD SPEAKER RECEIVER Makes its Bow

First of a Series of Articles Describing a Radically New Circuit Which Gives Astonishing Results

By Edward H. Loftin and S. Young White

Biography of Edward H. Loftin

Edward H. Loftin was born in Montgomery, Alabama, in 1885. Following his graduation from Annapolis, he entered the navy. As a Lieutenant Commander he began special work in electrical communication. In 1915, following further studies at Annapolis, he was assigned to pioneer development of radio for aircraft for the Navy. During the World War he served in France as radio and communication officer, and was a member of the Inter-Allied Radio Technical Committee. At the end of the War he continued his investigations and research in the United States. Today he is recognized as a patent expert—in which capacity he materially aided B. F. Miessner—and a constant contributor and worker in the field of radio research. Most of his work is now carried on in the Loftin-White Laboratory.

Biography of S. Young White

S. Young White was born in New York City in 1901. When he was sixteen years old he entered the Electrical Research Development field in the test department of the General Electric Company. There followed several years of varied and helpful experience in electrical and radio operations and practice, with this and other companies. In 1924 he became associated with Edward H. Loftin in the Loftin-White Laboratory of New York. Here he experimented with electrical communication research and development. He is particularly well-known for his work in connection with the Loftin-White systems of non-reactive plate circuit for preventing oscillations in tuning radio frequency amplifiers and constant coupling. His work on direct-coupled amplifiers and detector-amplifiers has for some time created great interest among technical men.

AMPLIFICATION of audio frequencies has heretofore been accomplished either by the transformer or by resistance coupled methods. This article is the first of a series describing another system which, although also of an early origin, has been lying dormant.

The system referred to is the direct-coupled type in which the plate of one tube is directly connected to the grid of an adjacent tube, with no transformer or condenser between, thus providing a system capable of both amplification and detection-amplification.

It has long been recognized as the soundest system of the three theoretically, but as possessing certain drawbacks which had to be overcome before it could be brought into general use. In spite of this, however, laboratory use has been made of this system in cases where amplification with minimum of distortion was so necessary as to justify the extreme inconvenience of operating the system.

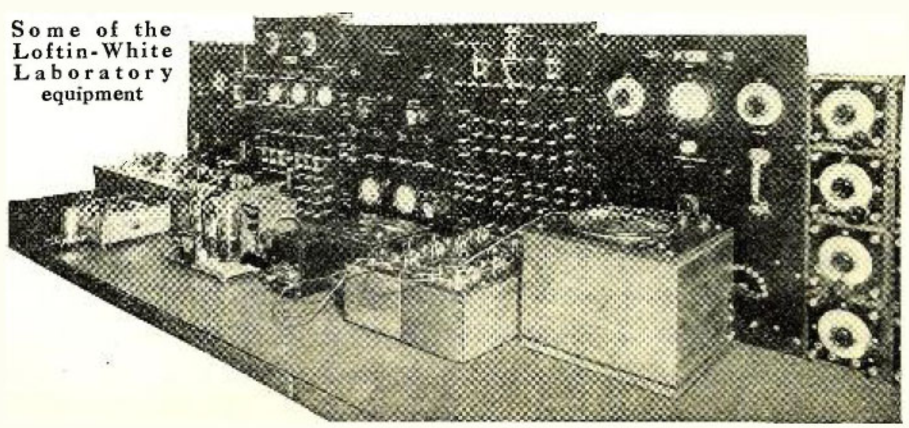
Some of these difficulties of operation we described at length in a paper delivered before the Institute of Radio Engineers and published in its Proceedings for March, 1928. We called particular attention to a tendency toward what might be termed "drifting," and described automatic methods for controlling this drift. We also discussed operation of the tubes at very high plate impedances, and very low plate currents, and consequent advantages.

Our direct-coupled system adapted to battery operation was described and discussed in the August, 1928, issue of RADIO NEWS (p. 146).

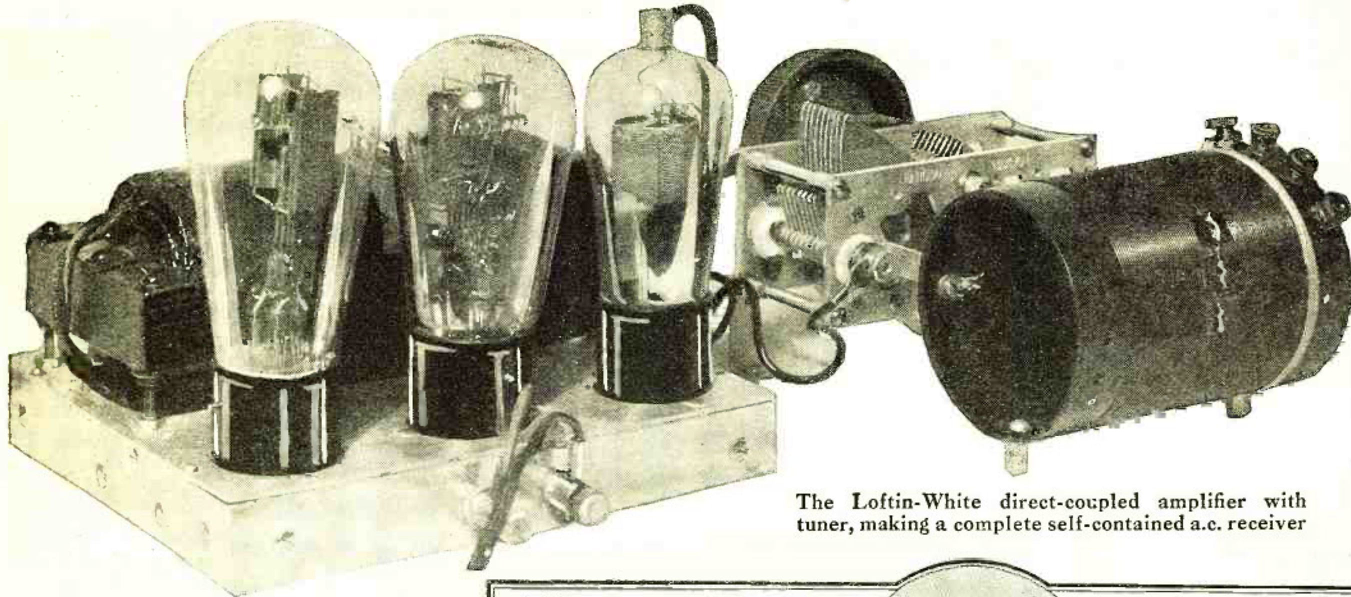
Some time before the delivery of the Institute paper, development work had been undertaken to make the system entirely a.c. operative, and it is our purpose to describe in a series of articles to follow in RADIO NEWS the difficulties we met and how they were overcome.

The first difficulty encountered was the lack of commercial hi-mu a.c. tubes, thus necessitating the carrying on of work with experimental tubes designed to our specifications. Both the heater type and the filament type, some of the latter operating with as low as ¼ volt on the filaments, were used.

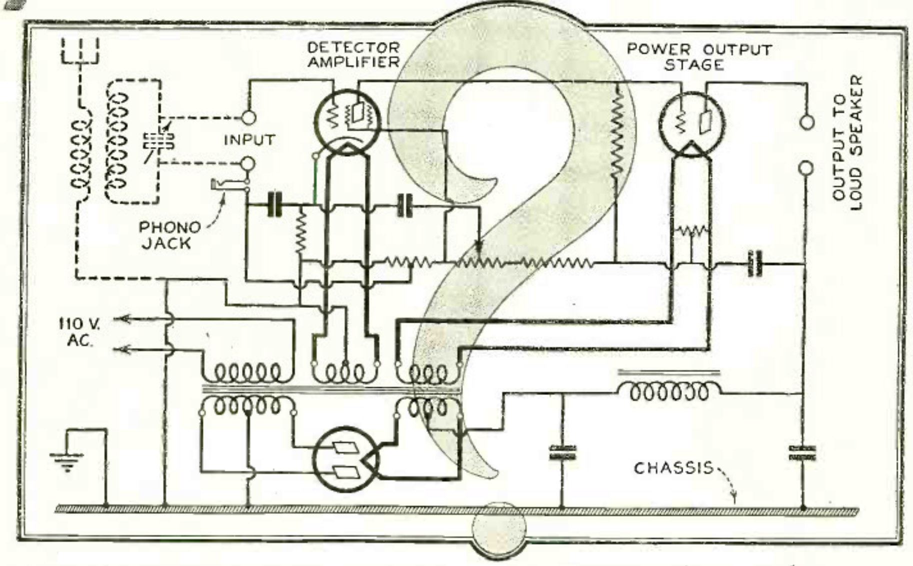
Since the amplification of the system was as high at 60 cycles as at other fre-



Some of the Loftin-White Laboratory equipment



The Loftin-White direct-coupled amplifier with tuner, making a complete self-contained a.c. receiver



Can you figure out the constants of this new circuit? They will be given in the February number

quencies, it was anticipated that considerable hum difficulties would arise in a.c. operation. Not only did these difficulties materialize, but in addition various incidental hums, usually obscured when the tubes are operated at normal impedances, proved noticeably annoying when operating at the very high impedances and very low plate currents which we used.

An entirely new series of automatic drift control arrangements particularly suitable for a.c. operation was developed.

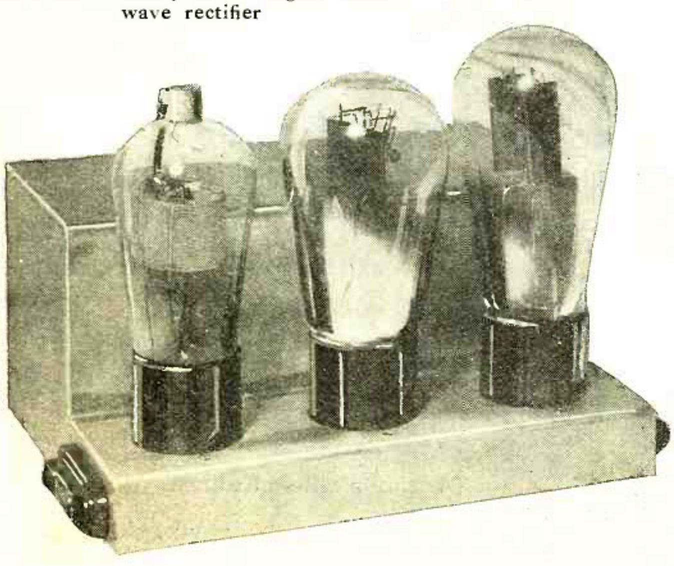
Another difficulty was a motor-boating tendency, emphasized by improperly designed drift correctors, and which we had to overcome without resorting to the large condensers usually relied upon for such work.

There is also a form of blocking peculiar to direct coupling and known as trigger action. This effect, while fatal to the use of direct coupling as an amplifier, was ingeniously employed by Minorsky to form a supersensitive circuit breaker.

In seeking solutions for the above difficulties, a primary limitation was necessary in order to keep material cost at a minimum. The accompanying photographs, showing the extremely small size of completely a.c. operated amplifiers and detector-amplifiers, clearly show how successfully this was accomplished.

We were able to discount these difficulties from the

Another view of the amplifier. At the left is the screen-grid detector. Center: 245 amplifier. Right: full-wave rectifier



THE authors of the accompanying article are men who have devoted most of their lives to radio research. Commander Loftin was appointed to the U. S. Naval Academy from the State of Florida, in 1904, and was graduated in 1908. He began specializing in electrical communication in 1910, and since that time has held many important posts, some of which include: Radio Officer of the U. S. Naval Aviation Forces in France during the war, with headquarters in Paris; Technical Representative of the Navy Department in the negotiation and arrangements for the construction of the Navy's tremendous transmitting station near Bordeaux. He has been in charge of the U. S. Naval Radio and Sound Signalling Research and Development in the Bureau of Engineering at Washington.

Mr. S. Young White, the co-author of this article, began his radio research work in 1917 when he entered the Electrical Research and Test Department of the General Electric Company at the age of 16. At that time he assisted the famous Mr. Hoxie in the development of various types of sound reporting and sound reproducing equipment. Since then he has developed, with Commander Loftin, a group of radio circuits which have been patented. Some of these patents were recently sold to the Radio Corporation of America.

The latest development from the Loftin-White Laboratory receives its introduction to the world in general in the accompanying article. We have witnessed radio demonstration of all kinds, but we feel free to admit that the demonstrations of equipment which we have seen at the Loftin-White Laboratory are completely revolutionary in character, and we feel that our readers also will be pleased to know that a complete description of the various applications of the circuits developed by Loftin and White will appear in a series of exclusive articles in forthcoming issues of RADIO NEWS.

beginning, because we saw some very promising advantages. Chief among these was our ability to balance out, through "hum-bucking," not only the fundamental hum currents, but also all harmonics, an impossible accomplishment in any system employing either phase distortion or wave form distortion.

The frequency range of amplification is astonishingly large when screen-grid tubes are used, running with gradual attenuation from a few cycles, depending on the time-constant of the particular drift-corrector, to a point where amplification ceases—at about three million (3,000,000) cycles. The high frequency end is extended to this astonishing limit by the screen-grid tube, which does not allow the capacitatively reactive plate circuit to cause degeneration through the tube capacity.

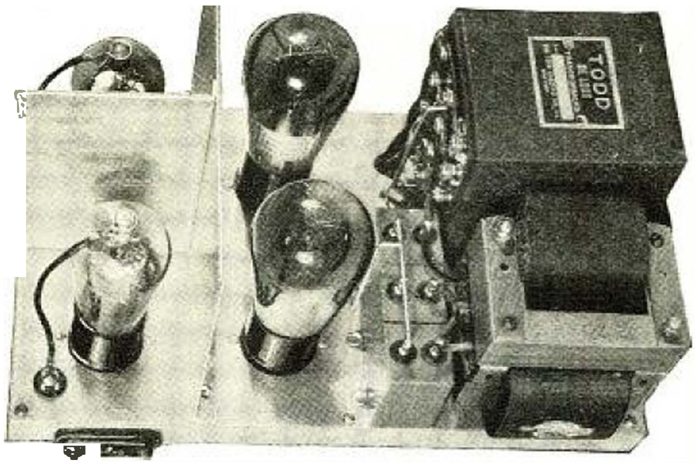
Very high amplification per tube is obtained, averaging about 100 per stage. Due to the absence of iron in the system, we have to shield only electrostatically against hum and stray pick-up, so that we can make the apparatus extremely compact with no hum pick-up.

When the system is used as a detector-amplifier, it automatically alters from an extremely sensitive condition when no carrier wave, or very weak one, is impressed thereon to a heavily biased (10 to 20 times initial) power handling condition for strong signals. This biasing is automatically regulated by, and in conformity with, the strength of the carrier wave itself.

In detector operation the shield grid tube prevents reverse feed-back of the radio frequency from the plate circuit, so that its load on the tuned input circuit is very small. This permits a much higher resonant voltage rise than with the normal detector and a consequent increase in sensitivity and selectivity, as viewed from the plate circuit of the preceding radio-frequency tube or antenna circuit. The system, comprising but two tubes and operated from either an antenna or a preceding radio-frequency tube or tubes, has the same order of sensitivity as the grid leak detector and two-stage transformer, coupling three tube systems without the detector overloading features of the latter.

We shall cover more or less specifically, in our succeeding articles, applications with numerous special and beneficial features, such as detector-amplifiers for radio receivers; a very high gain, distortionless amplifier suitable for photo-electric cell operation; a phonograph amplifier; a broad-band amplifier for television; and an amplifier for modulation amplification for transmitting. In connection with transmitter modulation, we can overload a quarter kilowatt tube from an ordinary 224 screen-grid tube. Many other uses will of course be suggested or become apparent.

The photographs shown in connection with this article give some idea of the small amount of apparatus required, especially for high gain operation. Further, they illustrate the compactness which will undoubtedly characterize receivers not of the coming season alone, but of the future.

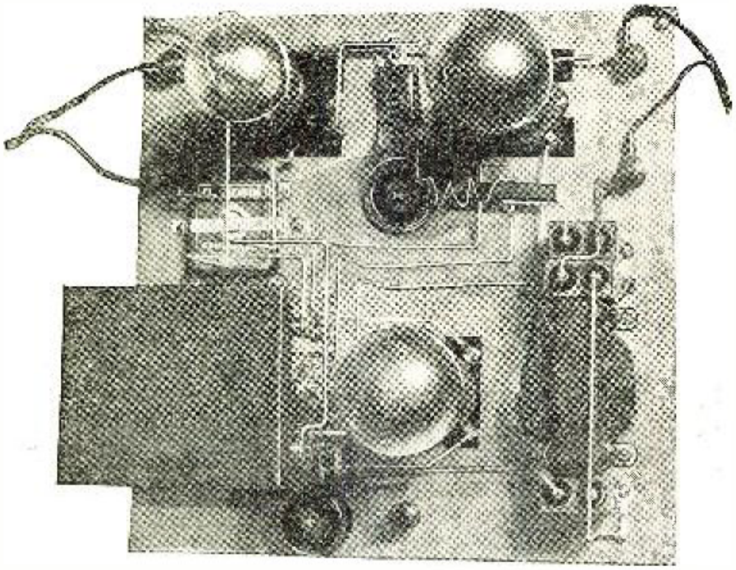


The Loftin-White three-stage direct-coupled audio amplifier and power supply, including full-wave rectifier

The Amplifier

New direct-coupled audio
few cycles to over 3,000,000
and requires no interstage

By Edward H. Loftin



Top view of a compact three-tube power amplifier-power supply device of the direct-coupled type, showing layout of the parts. The circuit is shown in Fig. 1

IN beginning the second of our series of articles covering a.c. operation of direct-coupled cascaded tube systems we deem it desirable to first include a brief statement of the problem as we view it so far as audio amplification and detection-amplification are concerned.

In any audio amplifier or detector-amplifier the following characteristics require attention: 1, frequency discrimination; 2, wave-form distortion; 3, hum, if a.c.-operated; 4, reasonable gain from the tubes used; 5, cost; 6, manufacturing tolerances.

In a.c. operation of direct-coupled cascaded tube systems the characteristics depend upon or are influenced by the following features:

1. Maintaining the operation of all tubes at the midpoint of their operating or output current curves, or what may be termed stabilizing against "drift" tending to arise from (a) changing tubes (they are not all alike), (b) change of constants or conditions due to (a¹) aging of resistors, (b¹) temperature coefficient effects in resistors, (c¹) line voltage modifications, (d¹) grid emission from tubes, (e¹) gas current in output tubes, (f¹) manufacturing tolerances.

2. Feedback phenomena at audio frequencies; 3, the hum problem; 4, motorboating; 5, trigger action; 6, maximum gain of tube; 7, providing current for auxiliaries, such as speaker field, and 8, increase to very high gain, such as that required by photo-electric cell operation.

Since the direct-coupled cascaded system is usable as a most effective detector-audio amplifier, it is well to keep in mind the following desirable features of which the system is capable in addition to those listed above:

1. Low grid bias for weak carrier currents and high grid bias for strong carrier currents, automatically self-adjusting.

2. Supply of potentials for the radio-frequency tubes sufficiently filtered to prevent modulation hum.

For those of our readers who may wish to construct an a.c.-operated direct-coupled amplifier we shall outline the

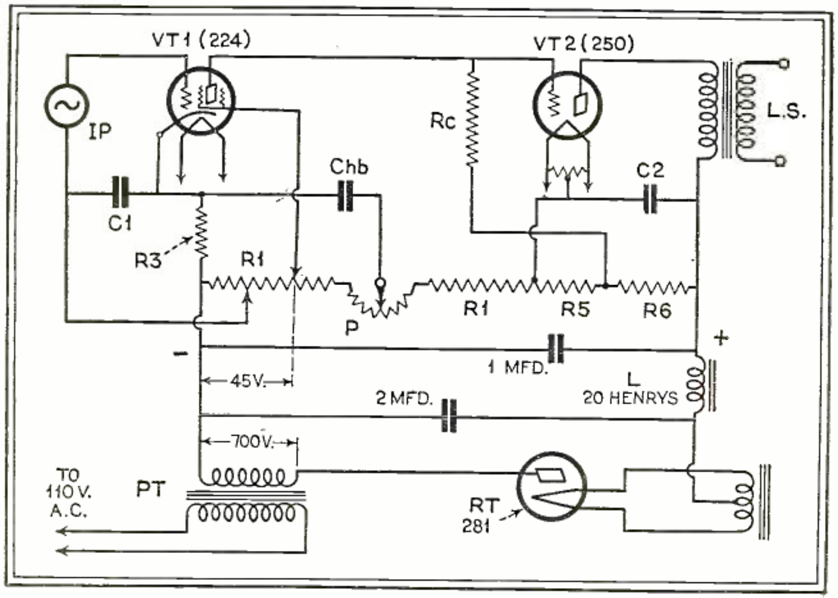


Fig. 1—Here is the direct-coupled audio amplifier and power supply circuit with values of parts employed as follows: VT1, -24 tube; VT2, -50 tube; R1, 5,000 ohms; R3, 25,000 ohms; R5, 100,000 ohms; R6, 300,000 ohms; Rc, ¼ megohm; P, 400 ohms; Chb, .1 mfd.; C1 and C2, 1 mfd.

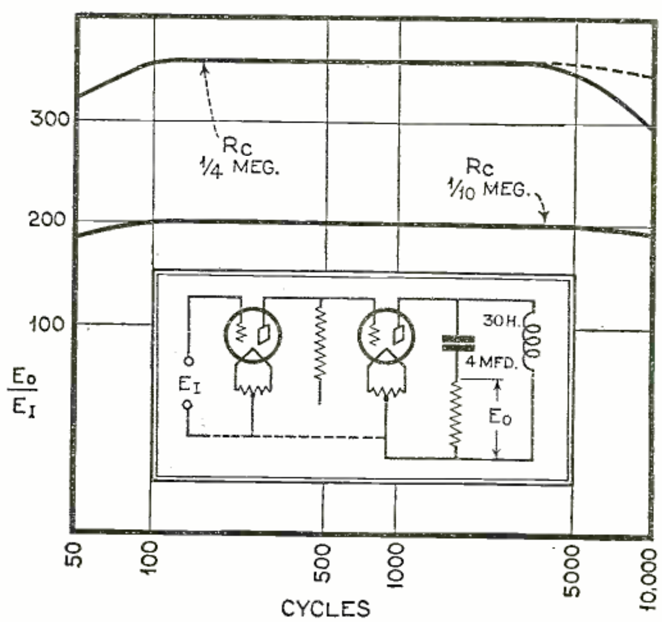
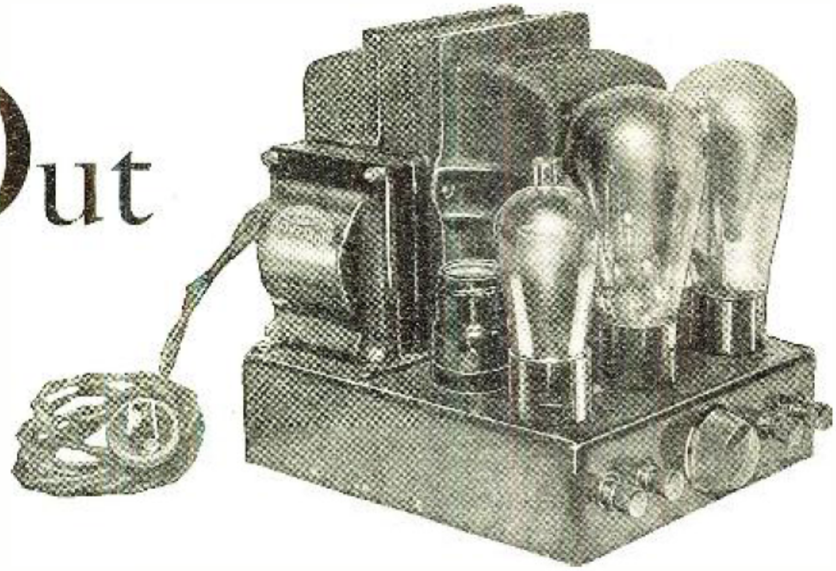


Fig. 2—Two curves which illustrate the direct-coupled amplifier's flat, equal frequency response over a band of from 50 to 10,000 cycles. The insert circuit shows the output system employed in obtaining these curves

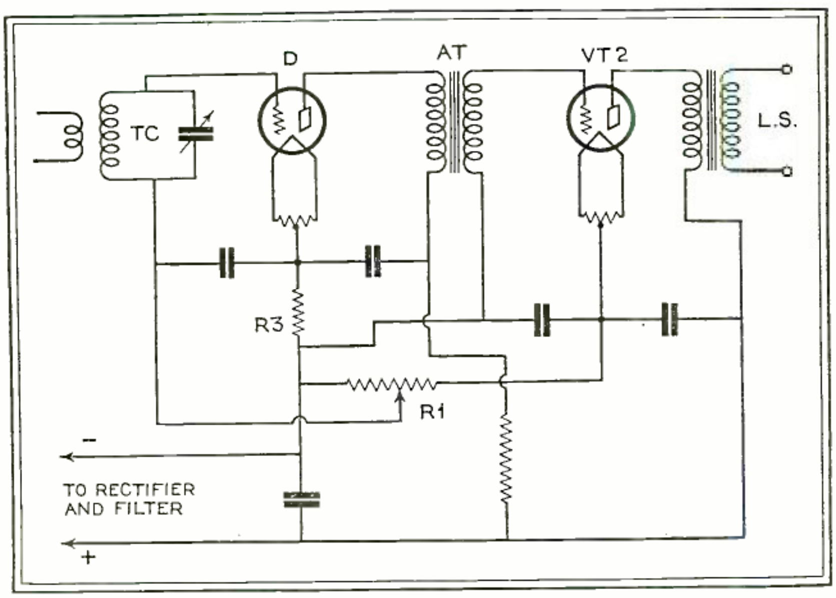
Steps Out

circuit covers range of
—is of simple design
coupling apparatus

and S. Young White



Transformer, tubes, resistances and condensers, all compactly arranged . . . and there you have the Loftin-White direct-coupled amplifier



¶ *Truly embracing a new amplification theory, the Loftin-White direct-coupled amplifiers undoubtedly will bring about a revision of accepted amplifier principles.*

¶ *Utilizing only two tubes, and a rectifier in the power supply unit, tremendous amplification, combined with a signal frequency response which is amazingly flat over a wide frequency range, is obtainable with the direct-coupled system.*

¶ *Compactness and simplicity of construction, almost beyond description, characterize these new amplifiers which bid fair to exert a deciding influence over future receiver design.*

THE EDITORS.

details of a system which we have found to give highly satisfactory audio amplification and detection-amplification results. The system is diagramatically shown in Fig. 1.

Forget Former Conceptions on Audio Amplifier Theory

In preparation for following our discussion of direct-coupled systems we suggest that the reader relax from his current conceptions and practical knowledge of tube and circuit characteristics and operation effects familiar in other systems for the reason that there are many occurrences and effects in direct-coupled systems which materially broaden our appreciation of tube and circuit operation and which, at first, may seem radical and perhaps questionable. We have only adjusted ourselves to these attributes through repeated verification of the results accompanied by persistent analyses for the causes.

The Circuit's Constants

Fig. 3—The sensitive handling of weak signals and the powerful handling of strong signals in the so-called power-detection circuits is aided materially by the adaptation of the drift-corrector and automatic bias arrangement as shown in the above circuit

Fig. 1 is a simple 2-tube system comprising a -24 screen grid tube (having a mu of about 400) as input and a -50 power amplifier as output, supplied from a single-wave -81 rectifier. The power transformer PT should deliver about 700 volts to the -81 rectifier. The filter comprises a single section having condensers of 2 microfarads and 1 microfarad spanning a choke having about 20 henries under load, connected as shown.

The potential developed by the filter is about 650 volts at 50 milliamperes, 400 volts of this being applied across the plate impedance of the 250 output tube through selecting the resistance of the arm R1 (about 5,000 ohms) to develop a potential of 250 volts at 50 milliamperes. A condenser, C2, of about 1 microfarad is needed to form a local signal circuit in the output circuit including association of any suitable loud speaker as indicated.

A coupling resistance, Rc, of ¼ megohm, capable of standing the small current of 750 microamperes, is suggested for the present Fig. 1, though in later articles of the series we will discuss wide variations in results securable through changing the value of Rc all the way to megohms. We also suggest 25,000 ohms as the value of bias resistance R3, but in later articles will comment on changes of value at this point. Filter condenser C1 should have a value of (*Continued on page 763*)

The Amplifier Steps Out

(*Continued from page* 705)

about 1 microfarad, a low-voltage condenser being altogether satisfactory.

For hum elimination by bucking, the potentiometer P of about 400 ohms is inserted in arm R1 far enough from the negative leg of the filter to leave a full 45 volts for the screen-grid connection as shown. The potentiometer contact arm is connected to the cathode of Tube VT1 through a condenser Chb of some value below 1/10 microfarad, selection of the value of this condenser being such that the hum minimum is had with an approximate mid-point setting of potentiometer P.

We have planned Fig. 1 to operate with 180 volts on the plate of VT1 and a like difference of potential across Rc to have what we term "symmetrical operation," which is nothing more or less than matching internal and external output impedances. Operation with much smaller potential will be pointed out in later articles. Since we have provided for only 250 volts total in arm R1, 110 volts more is needed to come up to the required double of 180 volts, or 360 volts. combined plate potential for VT1 and drop in Rc. This we acquire by inserting high resistances R5 and R6 (100,000 and 300,000 ohms respectively. for example, the matter not being a critical one) and connecting Rc to the junction point between them as indicated. thus adding the 100 or more volts of R5 to the 250 volts of R1.

Since the 250 tube VT2 does not need as an operating grid bias the full 180 volts across Rc, the opposing 110 volts or more of R5 nicely cuts this potential down to a desirable 70 volts. thus meeting 250 tube operating requirements. It is to be noted that the total of 400.000 ohms of R5 + R6 prevents increase of current drain on the filter beyond 1 milliampere.

In the beginning of the present article we referred to an effect we term "drift" in cascaded direct-coupled systems. and pointed out many sources of the tendency. In our article in the March. 1928, Proceedings of the Institute of Radio Engineers, the effect was discussed in detail. While we have devised a number of arrangements effective for drift prevention, which will be described in future articles, the drift-preventer of Fig. 1 is decidedly effective and most interesting. It functions as follows:

Circuit Is Self-Regulating

The combined plate current and screen grid current flow from VT1 through R3 develops a negative potential available for the grid of VT1, and with R3 about 25,000 ohms as previously given this potential may be about 25 volts. This is too much initial bias, and is accordingly reduced to an initial approximate 2 volts by connecting the grid-return to a point about 23 volts positive on R1 as shown in Fig. 1. If all constants and potentials of the system have been carefully selected as previously set forth, this initial bias will now establish the plate current of VT2, and therefore the current through arm R1, at about the 50 milliamperes that indicates operation at the midpoint of VT2's output current curve.

Now considering, for example, the worst encounterable cause for tendency to drift, that is, the impressing of a strong carrier current on the input of VT1, the result is a rectifying action tending to increase the plate screen-grid current of VT1. This increase of current tends to increase the potential across Rc, and therefore the negative bias on VT2, resulting in a tendency to lower the output current of VT2 and consequently the current in arm R1, the tendency lasting so long as the carrier is impressed. For correction opposing this drift tendency, however, we have the increase of combined plate and screen-grid current through R3 tending to increase the negative potential developed in R3 and, at the same time, the tendency for lower current in R1 to lessen the positive potential of the point in R1 to which the grid of VT1 is connected. That is. the correcting change of grid bias on VT1 is developed differentially, and at a greater rate than the change of current through R3 alone, so that drift cannot proceed very far before being arrested with a round turn, so to speak.

Summarizing this effect, it is seen that the correction system provides for starting with an initial low bias most sensitive for weak signals and automatically converts itself into a varying degree power handler as called upon to do so through increase of strength of incoming carrier.

It is obvious that a drift corrector so effective for carrier current is more than adequate for correction of the milder drift tendencies arising from changes in line voltage and manufacturing tolerances in tubes and resistors, previously mentioned.

How to Use the Circuit

To use the system of Fig. 1 the indicated input IP may be either a tunable circuit coupled to an antenna or the output of a radio-frequency amplifier, or may be an audio-frequency device, such as a phonograph pick-up including a volume control. The phonograph pick-up should be insered directly in the input circuit, and not through a step-up transformer.

We lay particular stress upon the fact that the system imposes negligible load on a tunable input circuit. so that damping is extremely low compared to other detector systems, and selectivity high. For this reason we also caution that if a neutralized radio-frequency system is placed in advance of the system of Fig. 1 it may be found not adequately stable under the light load if originally stabilized for operation with a heavier loading detector system.

System's Effectiveness Graphically Shown

The two graphs of Fig. 2 give some idea of the effectiveness of a simple 2-tube system such as that detailed in connection with Fig. 1. The logarithmic abscissae and linea ordinates show the measured and plotted voltage gain throughout the entire audio range, the upper graph being for a ¼ megohm value of Rc as specified for Fig. 1, and the lower graph being for a reduction of Rc to 1/10 megohm along with other modifications which will not be taken up at the present time.

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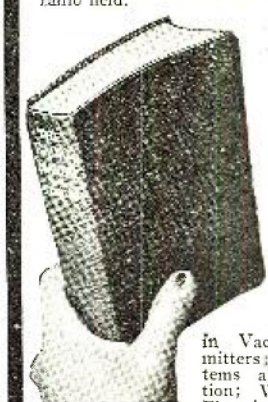

The Amplifier Steps Out

(*Continued from page 763*)

The skeleton diagram superimposed on Fig. 2 shows and states the details of the output system employed in measuring for these graphs.

The 1/10 megohm graph shows the substantial gain of 208 uniform from 140 cycles to 5 kilocycles with a loss of but 10% of the low point of 50 cycles and a loss of but 6% at the extreme range of 10 kilocycles. These end droops can in large part be accounted for in the frequency-reactance relations of the output circuit, substantiating the theoretical constancy of the direct-coupled amplifier *per se*.

The ¼ megohm graph shows the much greater gain of 360 (80% increase) substantially uniform from 140 cycles to 3 kilocycles, but an increase of loss to 16% at the 10-kilocycle point. This increase of loss is, in part, due to an increase of feed-back effect through the internal capacity of VT2 with increase of value of coupling resistance Rc. We cure this effect by simple feed-back neutralization as indicated by the dotted portion of the graph, so that the high gain continues much beyond the audio range, but this feature will be left for later treatment.

The desirable features of direct-coupled systems are also useful elsewhere. The drift-corrector and automatic bias arrangement of Fig. 1 has characteristics that fit nicely into the present practice of so-called power detection to aid in adapting the detector to sensitive handling of weak signals and powerfully handling strong signals. How this may be done is shown in Fig. 3, and the results may be quickly verified by anyone having the apparatus at hand.

Capable of Handling Weak or Strong Signals

In Fig. 3 D may be a detector tube of any type, a -27 for example, having a tunable input circuit and an output circuit coupled to a power amplifier VT2, a -50 for example, or any push-pull arrangement, through a transformer AT. R3 is a high resistance through which the plate current of detector D flows, thereby developing a potential which will materially change with rectification of impressed carrier currents. R1 is a resistance through which the plate current of the output tube VT2, or push-pull tubes, flows to develop the high bias potential required for the output tube, for example, 70 volts for a -50 tube.

Obviously, return of the grid circuit of D to a selected point in R1 provides a positive potential for opposing the negative potential developed in R3, and the difference gives any desired initial bias on the grid of D. The values involved in creating the difference are extremely large, so that special effects can be obtained.

To appreciate the effects that may be obtained, assume that the unaffected plate current of D and the resistance R3 are made such that the negative potential across R3 is initially 72 volts, and this is opposed by the full positive 70 volts derived from the grid bias of the output tube, there is had an initial 2 volts for

(*Continued on page 765*)

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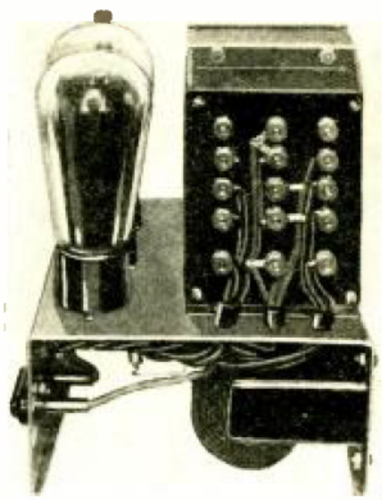
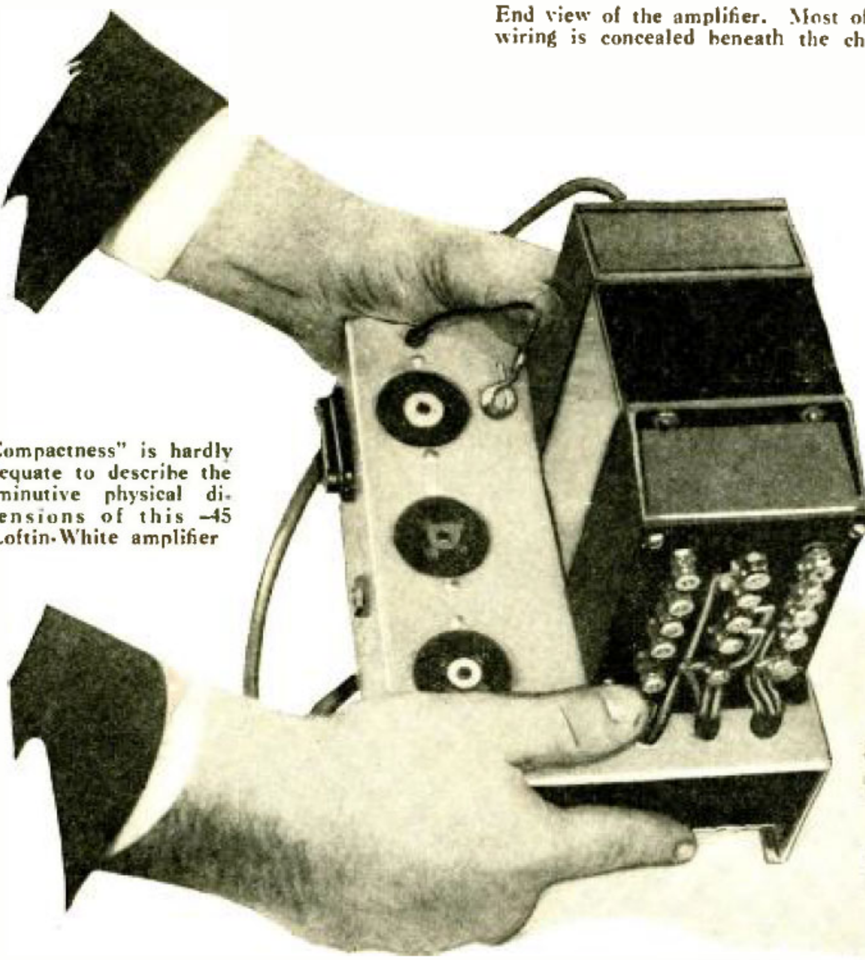
(*Continued from page 764*)

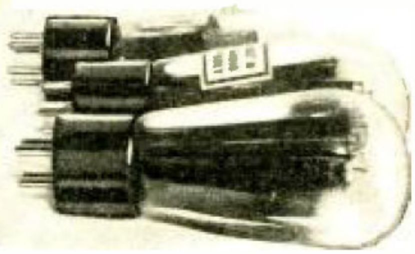
sensitive detection of very weak signals. Now should a strong signal be impressed to change the plate current of detector D by 25%, for example, the 72 volts original increases by 18 volts to 90 volts, and being opposed by the same 70 volts as before, the bias now becomes 20 volts, plenty to handle powerfully, very strong signals encountered in practice. It is seen that should R3 be used alone, there is no way to make it cover any such range of change of grid bias potential. In usual practice the bias is made initially high to handle powerfully strong signals, so that weak signals suffer and accordingly fail to come through.



End view of the amplifier. Most of the wiring is concealed beneath the chassis



"Compactness" is hardly adequate to describe the diminutive physical dimensions of this -45 Loftin-White amplifier



Building the Loftin-

Complete details and constants for able engineering development

By Commander Edward H.

THIS is the second article to be published containing the only authorized circuit constants of the Loftin-White amplifier, and the third of a series written by Commander Loftin and S. Young White exclusively for RADIO NEWS. Future articles will contain further details about the construction of this remarkable amplifier, which is conceded to be the most outstanding radio development in recent years, and destined to bring about far-reaching changes in the radio manufacturing world.

Future issues of RADIO NEWS will contain more details about the construction and the many applications of this almost revolutionary development.

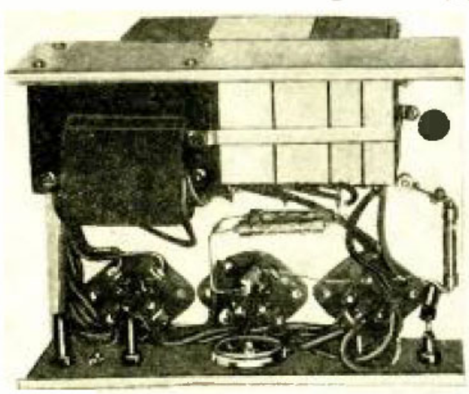
IN this third of our series of articles we had planned to discuss the underlying features of a.c. operation of direct-coupled cascaded tube systems, but we have received so many insistent requests for more details as to constructional features of a type of our system that we have taken occasion to design a 2-tube system from parts we believe generally available or obtainable, and having a -45 output tube as one modification over the -50 tube of the system described in our preceding article. The arrangement is diagrammatically shown in Fig. 1.

It is assumed that our preceding RADIO NEWS articles have been or will be read by those now interested, so that our present data are stated in the light of what we have heretofore covered. The output tube VT2 of Fig. 1 is of the -45 type, and therefore is operated with 250 volts plate potential and 50 volts negative grid potential, giving the normal -45 tube plate current of 30 milliamperes, these figures and others to follow being, of course, approximate within practical limits with normal line voltage. Once the system is properly set up the usual variations in line voltage will have negligible effect.

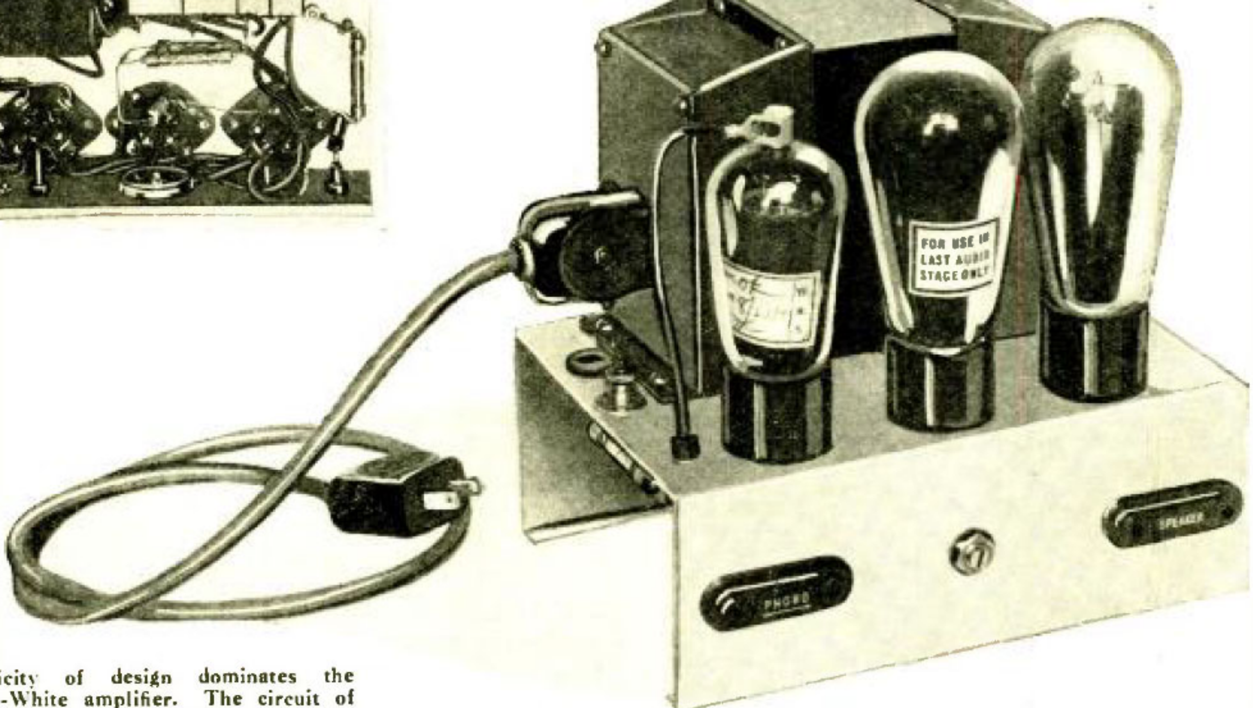
Input tube VT1 is of the -24 type, and for the constants hereafter given should preferably have the mu of 400 normal to commercial tubes of this type. Because of occasional leakage between the cathode and heater of commercial indirectly heated cathode tubes, we follow the customary practice of using separate heater windings on power transformer PT for tubes VT1 and VT2. It is preferable to connect one side of the heater of VT1 to point *a*.

Resistance arm R1, carrying the 30 milliamperes of plate current of VT2, is made up of four elements, R1a, P, R1c and R1d, totaling approximately 6100 ohms, and consequently, a potential of 183 volts. R1a is 425 ohms, developing about 12 volts; P is 200 ohms, developing about 6 volts; R1c is 775 ohms, developing about 24 volts, and R1d is 4700 ohms, developing about 140 volts. Thus, to supply the 250 volts for the plate of tube VT2 and the 183 volts for the arm R1, the filter system must deliver a total of 433 volts.

A 280 type full-wave rectifier tube, RT, is supplied through



Ease of construction is evident here. Tubes, a transformer, one choke, resistors and fixed condensers are all that enter into the assembly



Simplicity of design dominates the Loftin-White amplifier. The circuit of this one is shown on page 802

White Amplifier

building one type of this remark- are given here for the first time

Loftin *and* S. Young White

a power transformer, PT, wound to deliver approximately 400 volts a.c. to each plate of the rectifier tube, from which to develop, through our filter, the 433 volts rectified current required as arrived at above. The filter comprises a condenser Cf, of 1 microfarad in our case, although a larger value may be used, and a choke L of 20 henries, also subject to increase if desired.

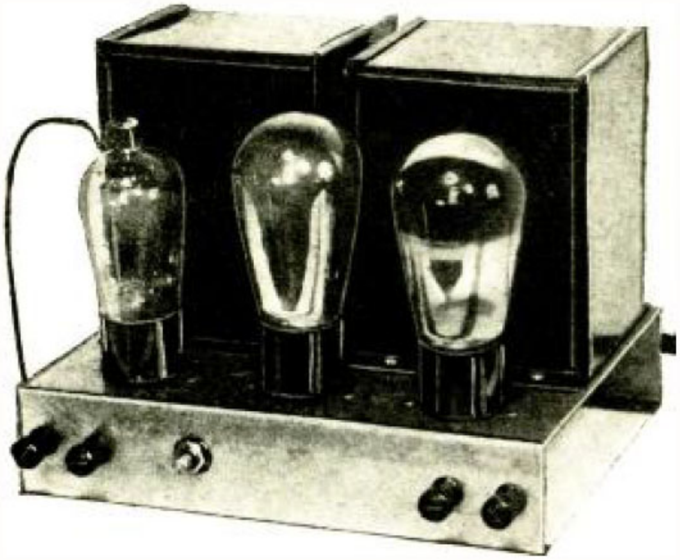
An output condenser C2 of 1 microfarad and a by-pass (around arm R1) condenser C3 of 1 microfarad are essential. The output capacity C2 may be increased one or more microfarads, as indicated in dotted lines by C'2, in which event an additional filter condenser C'f, indicated in dotted lines, of a value corresponding to that of C'2, must be included, but no change should be made in the value of C3, irrespective of what is done to C'2 and C'f. The purposes and reasons for these modifications to include C'2 and C'f, and the necessity for not changing the value of C3, wil be stated later.

Coupling resistor Rc has a value of ½ megohm, and should preferably have very low distributed capacity. We usually employ the internally treated glass tube type of resistors for coupling purposes. We have heretofore stated that the values of the coupling resistors may be varied through wide ranges for obtaining a variety of results, but suggest making no change in Rc in the present model until we have fully explained the procedure, the reasons therefor, the accompanying other modification of constants, and the results to be expected.

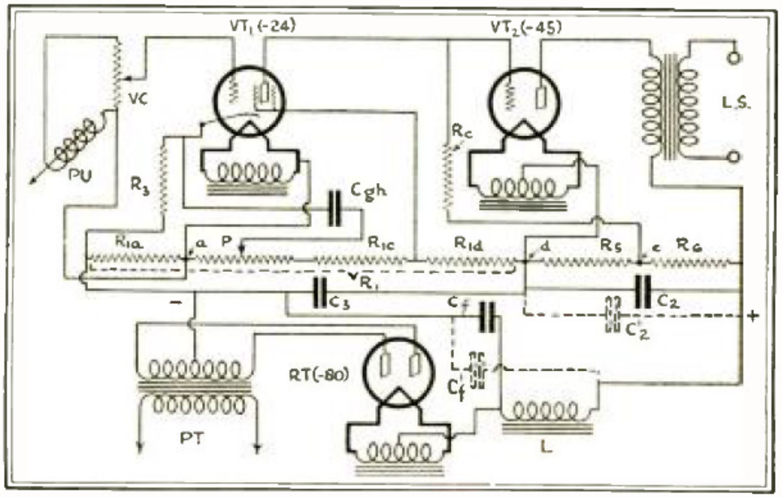
Resistor R3, as explained in our preceding article, coöperates with resistor R1a to develop initial grid bias for VT1, and to vary automatically the bias for drift correction or stabilizing, and for desirable bias change when receiving carrier currents of different intensities. In the present embodiment R3 is 50,000 ohms, and, with the combined plate and screen-grid current of VT1, develops a negative potential of about 14 volts with respect to the grid of VT1, which, opposed by about 12 positive volts in resistor R1a, provides an initial bias of about 2 negative volts for the grid of VT1. The current through R3 is only about 280 microamperes, so that the wattage or heat characteristics of this resistor are in nowise severe, thus making a suitable resistor for this function easily obtainable.

Resistor R5, of about 25,000 ohms, and resistor R6, of about 100,000 ohms (values not critical), divide the 250 plate volts of VT2 into two portions, with a junction at point *e*, to which Rc is connected, giving about 50 volts between points *d* and *e* while increasing the current drain on the filter a negiligible amount. These 50 volts added to the 183 volts across R1, less the opposed 14 volts in R3, give approximately 220 volts between the cathode of VT1 and filament of VT2. In order to follow out one of our principles of operation, termed by us "symmetrical operation," these 220 volts are equally divided (110 volts each) between the filament-plate impedances of VT1 and coupling resistor Rc. In other words, we substantially match the internal and external output impedances even when dealing with the very high internal output impedance of screen-grid tubes.

Having previously pointed out that the -45 tube used at



Economy is an outstanding feature of the Loftin-White system of amplification as exemplified in the one shown above, built from the Electrad kit. The constants for the -45 Loftin-White amplifier, to the right, are as follows: R1a, 425 ohms; P, 200 ohms; R1c, 775 ohms; R1d, 4700 ohms; Rc, ½ megohm; R3, 50,000 ohms; R5, 25,000 ohms; R6, 100,000 ohms; Cf, C2, C3, 1 mfd.; L, 20 henries. PU indicates the phonograph pickup and VC the pickup's volume control



VT2 requires but 50 volts grid bias, the 110 volts established across Rc are of course far too much for bias. The 50 volts of R5 are, however, opposed to this 110 volts in Rc with respect to grid and filament of VT2, so that the effective grid bias of VT2 is so close to normal that the self-adjusting characteristics of the system will automatically adjust for correct operation.

Taking into consideration the opposed potentials in R3 and R1a, the point c is about 28 volts positive to the cathode of VT1 (see preceding details of potentials); that is, the screen-grid of VT1 is operated about 28 volts positive.

The hum-bucking, grid filtering and screen-grid filtering features of the present arrangement include a modification of the arrangements for these effects described in our preceding RADIO NEWS article. Here we use but one condenser, Cgh, for these several functions, the condenser having a capacity value of 1 microfarad, and being connected between the cathode of VT1 and a contact arm on a 200-ohm potentiometer P. It is apparent that the 50,000 ohms of R3, coöperating with the 1 microfarad of Cgh, constitutes an effective filter for hum currents and signal currents, with respect to both grid and screen grid of VT1, but the variable connection of condenser Cgh to potentiometer P permits selection of a point where the hum introduced on the grid of VT1 is just right in phase and amplitude to buck out the hum currents arising throughout the system. The effectiveness, and the reasons therefor, of hum-bucking in direct-coupled systems were discussed in our preceding article.

In the arrangement of the preceding article a separate condenser of large value connected directly between the grid circuit and the cathode of VT1 was used for filtering, and a separate condenser of small value connected to a selected point in arm R1 was used for hum-bucking. Because of the small value of the hum-bucking condenser the hum-bucking potential selected from arm R1 had to be large. Obviously with the present arrangement the large value of condenser Cgh permits selecting a hum-bucking potential from arm R1 of much lesser value. In other words, in the present case potentiometer P is nearer the negative end of R1 than in the arrangement of the preceding article.

Output condenser C2 serves to localize signal current in the output of VT2, and thus lessen the signal current in arm R1, which may give rise to feed-back troubles. C2 is of course increasingly less effective for this purpose, the lower the signal current frequencies. By-pass condenser C3 serves to shunt both hum currents and signal currents from arm R1. While C3 was not used in the arrangement of our preceding article its use makes the matter of fixedly selecting the hum-bucking point in potentiometer P, with expectation of being satisfactory for hum suppression for any change of tube at VT1, more certain, and gives a better hum suppression for all tubes. In fact, when properly adjusted the hum is so low that a meter reading of it is quite difficult, unless there are leakage or grid emission currents in the particular tube used.

Once a location of potentiometer P and adjustment of its contact is had with by-pass condenser C3 in position, the value of this condenser should not be altered. The new value will not satisfy the original location and adjustment of P.

We have previously pointed out that additional output capacity C'2 and filter capacity C'f are not essential. They make for extreme refinement in the matter of delaying the falling off of amplification at frequencies so low that they are not reproduced in the present construction of dynamic and other speakers, so that the improvement is only detectable in precision measuring apparatus. However, in the event C'2 is added to include 1 microfarad or more, C'f should be added in capacity to match the addition in C'2.

The input of VT1 is shown to include a phonograph pick-up, PU, connected through a conventional resistance volume control, VC. Connection should be made directly in the input circuit as shown, a step-up transformer being both unnecessary and undesirable. The pick-up may be substituted by a conventional tunable circuit for radio work, but we do not advise trying to include any radio-frequency stages in advance of Fig. 1 until we have had opportunity to cover this phase of extension of the system. The operation of the arrangement directly from an antenna will give adequate idea of its extreme effectiveness both in sensitivity and selectivity as a detector-amplier.

A dynamic or other loud speaker may be used, but in view of the perfection of the frequency characteristic of the system we recommend using the very best loud speaker obtainable. In any event, once the system is properly set up, any distortion detected is a measure of the imperfection of the pick-up, phonograph records and loud speaker being used.

With the system properly set up a correct reading milliammeter in the plate circuit of VT2 should show approximately 30 milliamperes current with a line potential of 110 volts, and should not fluctuate noticeably during operation, provided output tube VT2 is not pushed to overloading.

The overall gain is in the neighborhood of 300, giving more than enough volume for phonographic operation with any satisfactory pick-up. The frequency characteristic is extremely good throughout the entire sound range. Not being corrected for feed-back in the output tube, there is a slight falling off at 10,000 cycles, but not enough to be noticeable in any reproducing apparatus now available. The detection and amplification of carrier current is most effective, and it is believed that a trial of this form of functioning will surprise those acquainted with what is accomplished by the usual apparatus employed.

Beginning but briefly, in the space remaining for this article, our theoretical comments on direct-coupled systems, the first important observation is that the (*Continued on page 873*)

Building the Loftin-White Amplifier

(*Continued from page 802*)

system is particularly well adapted for passing onward a large percentage of the high amplification of high amplification tubes. Other than the advantage of the extraordinarily good frequency characteristic we see no particular appeal in the system for the very low mu tubes that prevailed up to several years ago.

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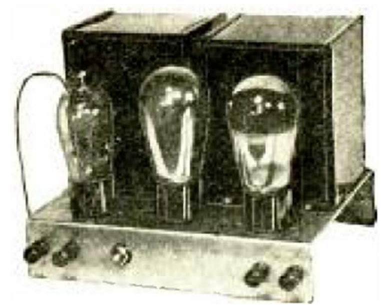

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