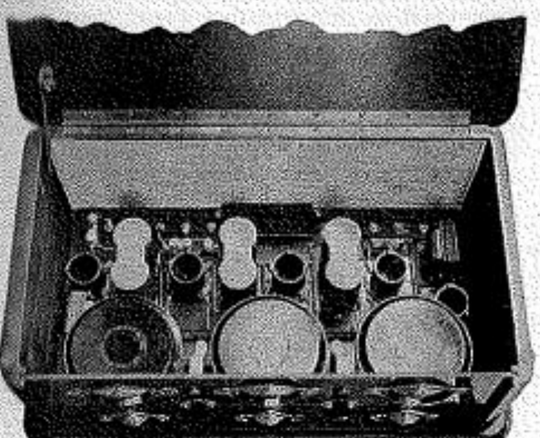
The Design of the Grebe Synchrophase

By R. R. Batcher*

IN the October issue of *QST* there appeared a short descriptive article on the new Grebe Receiver, the Synchrophase. Due to the interest which was aroused in the numerous features of this receiver, a short technical article will doubtless be of value to readers.

About a year ago the Research Laboratory Staff was enlarged and investigation of an intense nature began. Data compiled in previous years proved invaluable in determining just what lines should be concentrated upon. It is the intention of the author to discuss many interesting and instructive results that have been discovered during the investigation, which was along two lines: First—the circuit, and then the equipment that was to be used in the circuit.

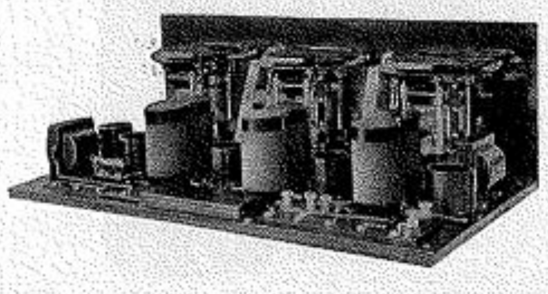
It was early decided that the whole question of tuned radio frequency amplifier circuits should be re-opened and a special consideration given to the multiple tuned stages having minimized magnetic and capacitative coupling. The main problem was to get the maximum amplification per stage. Besides this, the tubes should not oscillate. Toward this end many methods to prevent inductive coupling were investigated, includ-



ing the use of torodial coils, the mounting of coils, and other schemes, and in the end all were discarded. It was found that much superior results could be obtained with the use of the "binocular" coils, which were a distinctive feature of the new receiver.

The "Binocular" Coil

These tuning coils consisted of two inductance units connected in series. The coils are 1⅝" diameter and contain 85 turns of 20/38 Litzendraht. The turns are in the same direction on each of the two coils, and the lower end of the front coil is connected to the filament end of the circuit and the lower end of the rear coil is connected to the grid. The upper ends of both coils are connected together. In case the transformer



contains a primary, it is wound on a tube *inside* of the coil connected to the filament end. It will be seen that any inductive coupling from other parts of the circuit affect both coils alike but in opposite directions so that the total inductive coupling is zero. Another feature possessed by these coils is that they will not pick up energy directly,—no matter how near the receiving set is located to the transmitting equipment: therefore, *if the antenna and ground are disconnected, no signal whatsoever is heard.*[1] *This tends to increase the selectivity very greatly in congested districts where numerous stations are located.*

It was found that all capacity coupling and conductive coupling should be made as small as possible but the co-efficient of coupling (electro-magnetic) between the primary and secondary of these transformers was made as high as possible. The electro-static coupling between the primary and secondary was made very small.

During the determination of the transformer ratio it was discovered that the actual ratio did not affect the results directly, the idea being to make the secondary as large as possible, consistent with the wavelength range desired. Of course, the smaller the capacity of the tuning condenser, the smaller its wavelength ratio, as the minimum capacity of the condenser itself is *very small compared with the distributed capacity in the coils.* A large inductance increases the L/C ratio and increased selec-

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1. This is a feature in which most of our present receivers are sadly lacking—no matter what wavelength they are designed for. More discussion of this point will appear in *QST*.—Tech. Ed.

tivity results. Separation of stations 10 kilocycles apart is easily possible if they are not in the immediate vicinity.

The number of turns on the primary was found by experiment, the upper limit in general being where the circuits became unstable and oscillated.

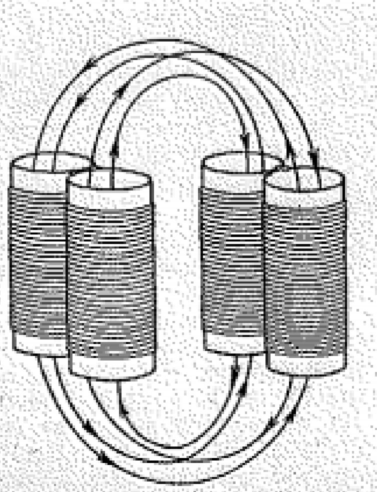
The use of small wire in winding the primary coils resulted in a very small elec-

BINOCULAR COILS

tro-static co-efficient of coupling, and the result was that a much larger primary winding could be used with a great increase in the amplification per stage but without increasing the tendency to oscillate.

The shunt capacity around the primary (either actual or distributed) should be low, otherwise the primary circuit has the tendency to follow the tuning of the secondary, and this strangely, plays havoc with the amplification and selectivity.

By keeping the primary circuits in a condition (by careful design of coils) where



FIELD OF THE BINOCULAR COILS

they do not "tune" with the secondary, the phase conditions in each circuit are such that any capacity fields from one part to another are not destructive. Thus, any tendencies to oscillate from this cause are greatly minimized.

The use of a large inductance in the tuning circuits required the use of a very small condenser. This condenser, as designed, required precision manufacturing methods since the spacing of the plates was only .014 inch, yet it can be assembled so uniformly that the dial settings match within a hairbreadth, extremely abnormal antenna capacity being the only cause of deviation in the first dial reading.

As mentioned before, the coils were wound with Litzendraht, but every strand of this cable must be *thoroughly soldered at each end and must be continuous throughout.* It was thought that a D.C. resistance test would show up a broken strand, but manufacturing variations in drawing down the No. 38 wire often make results doubtful, so a *high frequency resistance measurement test is used* to insure every coil as perfect.

The Variable Condensers

The variable condenser has a maximum capacity of 225 and a minimum of 6 micro-microfarads, and is the smallest condenser, as far as its physical dimensions are concerned, that the author has ever seen. The resulting static fields are very small and since the rotor and end plates are grounded, no body capacity effects whatsoever are noted. The shaft is vertical so that the condenser needs no balancing and the new types of dial and vernier (resulting from this style of mounting) are much more easily adjusted.

The rotor plates embody a departure in the design of condensers and follow a plan devised by the author shortly after the broadcasting station waves were separated into frequency bands. These condensers have been used in our tests for some time and it is found that tuning is very much simplified since stations which are separated by equal *frequency* distances are separated by equal number of dial divisions. This "Straight Line Frequency" formula, for the design of these plates, as the result of my investigations, is more or less complicated, but will be taken up in a future article. It may be stated that the plates following this law have a smaller area for the radius of swing, so that more plates are necessary. For this reason, only the first three-quarters of the capacity range on this condenser follows the straight line frequency law. The stations appearing where the dial is ordinarily crowded are thus evenly separated, but a few of the stations appearing on the upper end of the dial where the normal separation is great enough not to cause unnecessary trouble, the condenser follows the ordinary straight line capacity law.

There is little difference in circuits if the equipment in each circuit has equivalent losses. Therefore the interesting thing about the synchrophase is not the circuit but the design of the parts used in it. The synchrophase circuit transformers have double primaries, one of which is capacitively connected to the grid. It is found that the tube capacity feed-back is only a small portion of the coupling usually found. It was necessary then to find the source of every type of coupling and to eliminate as many of them as possible. Since the resistance in the oscillating circuit is very low, due to the condenser design and the design of the Binocular coils, it was extremely difficult to prevent oscillations in many experimental sets, and the final style is the result of careful study. As mentioned before, electro-static capacity between the primary and secondary is very important. The direction of the windings of the primary coil should be the same as the secondary coil, and the connections should be the same in each stage. To provide for operation with defective "B" and "C" batteries in which high resistance internal connections are found, one-microfarad by-pass condensers are provided across these batteries. The location of several leads in this circuit with respect to the others was very important. For instance, the grid return lead in the R.F. stages, connecting to the negative end of the "C" battery, is extremely sensitive to feed-back currents and its location required special consideration.

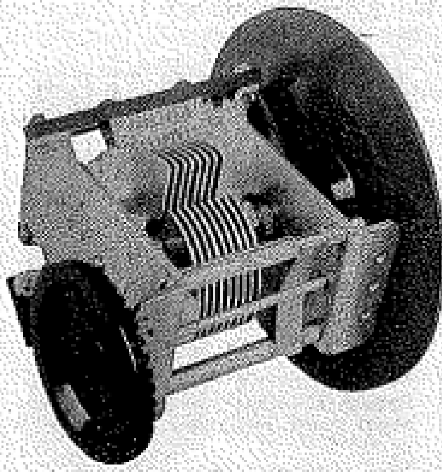
Each Synchrophase Receiver is tested for oscillations with 190 volts on the plates, *which is much more than should ever be employed by the user with the present type of tubes.*

There are many other details of interest which might be included here, but they will be held for another article. It is believed that many of these features may be applied to amateur receivers with remarkable results and preliminary tests have shown this to be true.

The Binocular coils, for instance, may be used for short wave receivers and as many stages of Radio Frequency Amplification can be used as desired, since the arrangement of the coils is not limited to three stages. The more stages used, the greater the experimental work necessary in eliminating feed-back due to conductive or capacity factors, but if one cares to experiment with the elimination of other types of coupling the results are worth-while.

In short wave receivers, the tube coils which comprise a Binocular Coil unit may be connected in parallel, instead of in series, taking care that the fields from the two halves are in opposite directions. This results in a smaller value of inductance with a much smaller radio frequency resistance. The author is working out a practical method of computing the correct number of turns for these coils for various wavelength ranges and the results will be available to the readers to be incorporated in an article later.

The Binocular coil was developed by Mr. P. D. Lowell, who devoted much effort toward the solution of the various problems encountered in connection with the design of the Synchrophase Receiver, and particularly with the design of the field-less coils. The Straight Line Frequency Condenser was devised by the author as a result of a survey of the requirements for the new tuned radio frequency receiver.



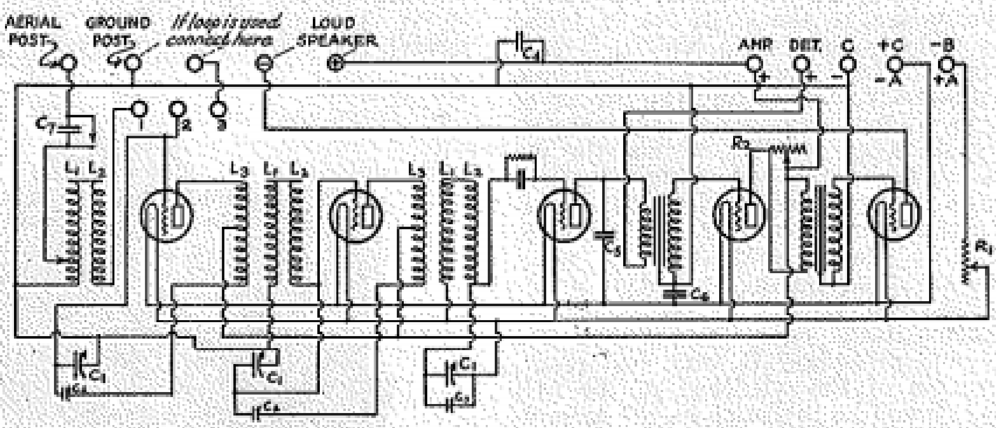
THE STRAIGHT-LINE VARIABLE CONDENSER WITH FRICTION VERNIER

The Grebe Synchrophase Circuit

OUR readers have so insistently demanded the circuit of the Grebe Synchrophase receiver that Mr. John M. Clayton, of our Information Service, has traced the circuit in one of these receivers and we are reproducing his sketch herewith.

The absolute accuracy of the circuit is not guaranteed as it is difficult to trace in the finished receiver. We wish also to point out that the performance of a receiver is not primarily due to the circuit and that anyone wiring up a set in accordance with this drawing will not necessarily get synchrophase results.

For a more detailed discussion of the set itself, see the article by Mr. Batcher which appears in this issue. Please pay especial attention to his statement that results depend on design and not on the circuit alone. It is also worthwhile to remember that Litzendraht is difficult stuff to use successfully and that Grebe does this only because every individual coil is measured at radio frequency to make sure that it is all right. If one doesn't want to do this it might be better to use solid wire in the first place. The inductance of the two secondary coils in series is about 350 millihenries, the range of the variable which employs standard tubes. The MU-2 employs UV-199 or C-299 tubes and employs six of them. We are not quite sure but suspect that the additional one is used



C6 & C1—Bypass condenser, ½ µfd.

C4—Bypass condenser, 5000 µµfd (.005 µfd) about right but other capacities should be tried.

C7—Fixt antenna series condenser of small capacity. 100 to 250 µµfd (.001 to .00025 qfd) will serve. Use a good mica condenser.

R1—6 ohm rheostat.

R2—Volume control, variable high resistance. Should be continuously adjustable (not by steps) so fading can be counteracted. Bradleyohm suggested.

L1—74 turns Litzendraht (First L1 tapped 15 turns froq lower end).

L2—74 turns Litzendraht.
Note—The receiver froq which the diagram was traced used 47 turns, which is not in agreement with the 85 turns mentioned in Mr. Batchers article.

L3—18 turns No. 14, tapped at 9th turn.

C1—220 µfd (.0002 µfd) variable condenser. Grebe set uses straight frequency line type. Next best is straight wave length type, of which several good makes are are available.

C2—Stabilizing condensers, 5 µµfd (.000005 µfd), ordinary "neutrodones" will an-answer.

C3—Vernier condenser used to make dials 2 and 3 run together. A 5 µµfd condenser with screwdriver adjustment is desirable.
Important Note—If aerial is used connect post 1 and 2 together. If loop is used transfer this connection to posts 3 and 2.

condenser is from 5 to 220 micromicrofarads (.00022 microfarads). The secondary inductances are wound with Litzendraht having 20 strands of No. 38 wire. The primary is a single No. 40 wire. The circuit shown here is of the type MU-1 in parallel with the fifth one in the last audio stage.

The resistance connected to the plate of the first amplifying tube is actually a shunt across the amplifying transformer primary and acts as a volume control.

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Just as our forms close the 1924 Hoover Cup was awarded, by action of the League's Board of Directors, to Bartholomew Molinari of Station 6AWT, at San Francisco, Calif. Particulars will appear in our next issue.