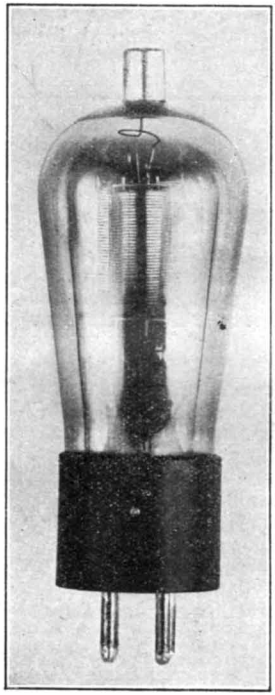
The UX-222 Shield-Grid Tube

By Robert S. Kruse, Technical Editor

THE audience for this story is not only interested but has been sitting on the doorstep and clamoring for the performance to begin. Everyone in the radio industry has of course known for a long time that some day there would be a commercial American two-grid tube and we have been urged to start talking about it. Unfortunately, talk is not very filling stuff and until the tube itself should arrive talk seemed worthless, for after all a tube that someone may have in a laboratory at Schenectady or Paris or Berlin does not help many of us to receive or transmit signals.

Now however, we have the tube; not only that but we have the shield-grid variety which seems to be the most desirable of the two-grid tubes. We can therefore begin to talk about a thing that is no longer a laboratory device but a commercial radio article with a great array of interesting uses — all of which may be bought over the counter as soon as the local radio store has managed to obtain a supply.



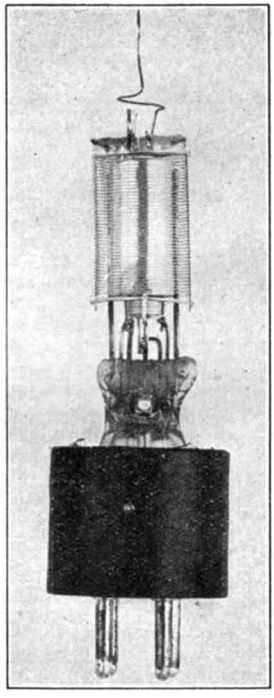
EXTERNAL VIEW OF THE UX-222 TUBE
Showing method of bringing the lead to the inner grid thru top of tube.

WHAT THE TUBE IS

First of all let us examine the tube's construction. Viewing the first photograph, we find that externally it looks like a CX-301-A with an additional terminal in the shape of a small brass cap where the tip of older tubes used to be. This cap connects to a small diameter spiral grid (see the "exploded" view) which surrounds the straight filament. This grid and filament appear to have been taken outright from the CX-220. Outside the grid there is quite naturally a cylindrical plate, of a rather larger diameter than the grid and filament would lead us to expect in an ordinary three-electrode tube or "triode".

The real difference comes in the "shield-grid" which is a sort of screen, insulated from the plate but covering both its outer and inner surfaces. Actually this screen consists (as the exploded view shows) of two overgrown spiral grids of close mesh but different diameter. One is of a size to slip between the plate and the ordinary grid, the other is of a size to fit over the outside of the plate. The two are connected together and brought out to the ordinary "grid" connection of the tube base.

As a final result we have a tube in which the plate is screened very thoroughly from the grid, even the *leads* from the two not coming near each other but being brought out at opposite ends of the tube. The question then naturally is--"Why should anyone want such a thing?" This automatically brings us to the uses of the tube.



STRIPPED VIEW OF THE UX-222 TUBE
Showing internal assembly with the "shield-grid" surrounding the plate.

These uses are appallingly numerous and almost all of them offer some show of usefulness in amateur radio. A very little thought will show that if after some 20 years we are still explaining the uses of the three-element tube (triode) then there must certainly be many more possible combinations for the four-element tube (tetrode). It is accordingly necessary to talk of the tube by the general process of suggesting the various ways in which it may perhaps be useful and supplying

enough information about the action of the tube to permit everyone to follow up his

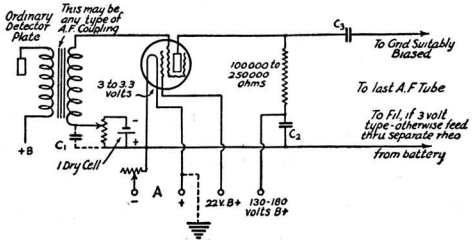


FIGURE 1. THE 222 USED AS A "SPACE-CHARGE-GRID" TYPE OF AUDIO AMPLIFIER

In this method of operation we can think of the inner grid as the source of the electrons on which the plate and outer grid operate This method of operation does not prevent feedback, hence is not advantageous for r.f. amplification. Since this is a "universal" diagram it must be modified to fit with various input and output tubes and to accommodate various tubes before and after the 222. If all the tubes use 3-3.3-volt filaments they may be operated from the same rheostat but if the other tubes are 5-volt type the 222 should have a separate rheostat. The grid of the tube following must be biased by resistance leak or inductance leak, each with a battery suited the tube.

C1 Optional but desirable, capacity ½μfd or more.
C2 Absolutely necessary if other resistance couplings ar used, capacity 1μfd or more.
C3 Mica condenser with leakage resistance above 100 megohms and capacity of .005 to .05 μfds. Only the better mica condensers will do, paper is rather hopeless.

own pet hobby in the hope that he will not swallow his own smoke but make a smudge with it so we may locate him, together with whatever information he has dug out during his trials.

THE SEVERAL STYLES OF 2-GRID TUBES

At the very beginning we find that there are several possible sorts of 2-grid tubes. Leaving out some of those that seem less important we have the following—

The space-charged-grid tube.

The two-grid tube with separate actions for the two grids.

The shield-grid (purpose for which the 222 is mainly designed).

The pliodynatron.

It is quite out of the question to make bare mention of all the possible ways in which these types can be used and again we must try to guess which will be of the greatest interest, leaving the others out entirely.

THE SPACE-CHARGE-GRID TUBE

The 222 may be used in the space-charge-grid connection, for audio amplification. Certain European types such as the Telefunken RE82 and RE212 may be used as audio amplifiers or (according to some experimenters) as detectors. With the usefulness of the 222 as a detector I have no experience, though the connection is given herewith.

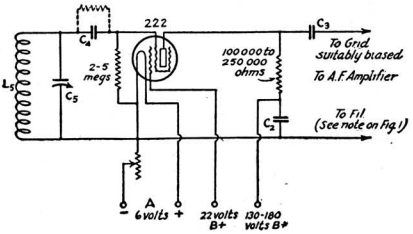


FIGURE 2. THE SPACE-CHARGE-GRID METHOD OF USING THE TUBE AS A DETECTOR

The same precautions must be taken with regard to filament voltages as were mentioned on Fig. 1. The constants are the same. L5 and C5 are chosen for the desired wavelength which may be anything that is wanted. C4 is the usual grid condenser. The leak may return to negative filament directly or across the grid condenser but care must be taken to avoid returning it to the battery side of any fixed resistors that may be used in the filament lead.

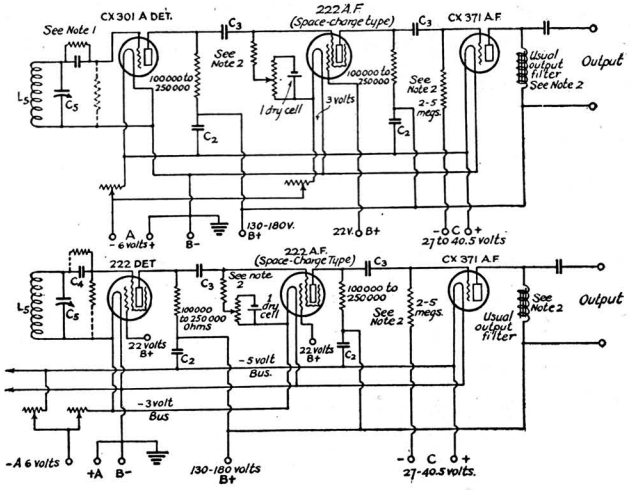


FIG. 3. THE SPACE-CHARGE-TYPE A.F. AMPLIFIER USED WITH DIFFERENT DETECTORS

All constants are as in Figs. 1 and 2. Note. 1—The grid return and position of the grid leak of this tube may be changed to suit the custom of the builder. Note. 2—The grid leak of this tube may be replaced by an audio-frequency choke.. If a tube other than the 371 is used the plate and grid voltages should be changed accordingly and if a 301-A is used the output filter may be omitted.. This last would not be advisable except in c. w. reception.

In the space-charge-grid connection the small grid next the filament is made *positive* by a connection such as that shown in Fig. 1. The purpose of this grid is now to

do away with the "space charge" which normally consists of a cloud of electrons hanging about the filament. These electrons are naturally snatched away by the positive grid, which increases the mutual conductance of the tube because the electron cloud normally constitutes a sort of screen. That is a sufficiently inexact explanation but will answer for the moment. The practical effect is to produce a condition under which the tube *operates* with a "mu" of 60 and at the same time maintains a mutual conductance high enough so that the voltage amplification obtained may run as high as 40. The plate resistance is high so that the output must be taken from a resistance coupling as shown but at the same time it is not so high as to destroy the usefulness of the high mu just referred to, as would tend to be the case if one attempted to obtain a mu of 60 with three elements.

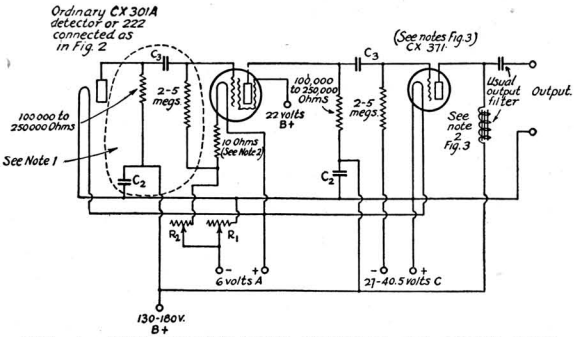


FIG. 4. THE SHIELD-GRID METHOD OF USING THE TUBE AS AN AUDIO AMPLIFIER

This is not the customary way of using the tube but it may be employed where high audio gain is desired, taking care not to operate above the power limitations of the tube. More than a single stage is seldom to be thought of and shielding of the input and output circuits is then practically essential just as in the circuit of Fig. 5. The shielding must of course be adapted to audio frequencies.

Note 1—The method of coupling the detector to the 222 amplifier may be of any sort suited to the detector tube used, the plate voltage being changed accordingly.

Note 2—The grid bias may be provided by the drop thru a 10 ohm resistance as shown, or by a C battery. It is not especially critical.

LOW PLATE VOLTAGE OPERATION

For some reason not at all clear to me there was some time ago a wild outburst of enthusiasm over the fact that a 2-grid tube may be made to operate as a detector or audio amplifier at very low plate voltages. For instance, the RE82 and RE212 Telefunken tubes previously referred to will perform as good audio amplifiers or as detectors with plate voltages in the vicinity of 4-15. The question then is—"What of it?" Dry batteries are neither expensive

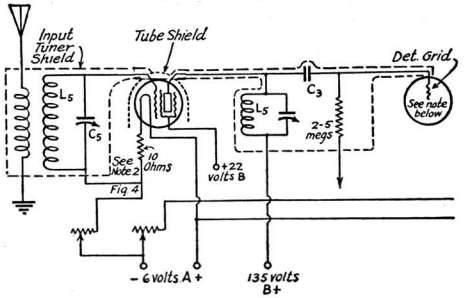
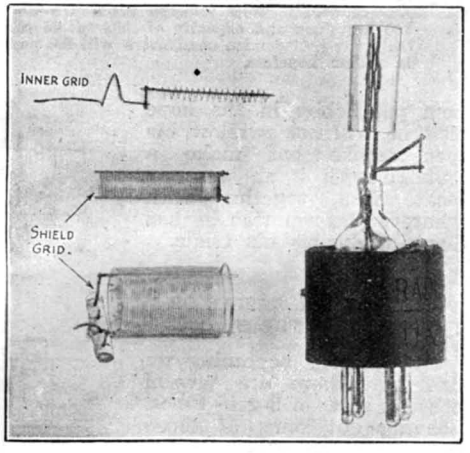


FIGURE 5. THE SHIELD-GRID METHOD OF USING THE TUBE AS AN R.F. AMPLIFIER

Examples of such use are shown elsewhere in this issue. The constants are as in the other figures. Note the connections to the detector are shown in an incomplete manner because of the very many possibilities. Thus the grid leak may return to the positive or negative filament or to a C bias depending on the use of the set while the plate circuit may contain a tickler coupled back to the second L5, or a separate tuned circuit not coupled back or may simply feed a headset or loudspeaker or an amplifying transformer primary. All this has no effect on the arrangement of the r.f. stage with the exception of the tickler which must enter the detector shield in a suitable manner as shown in the sets described in this issue.



EXPLODED VIEW OF THE 222

At the upper left is the inner grid, consisting of a wire spiral welded at each turn to a straight wire. This wire is supported at the upper end by the glass bead as seen in the stripped view while the lower end is held in line by projecting into a disc of lava resting in the lower end of the inner part of the shield grid, shown next below. The filament passes through the exact center of the same lava disc and goes up thru the center of the inner grid to another support held by the glass bead. The inner grid is used as the control (input) grid when operating by the shield-grid method but is biased positively and used as a space-charge grid when operating under the space-charge method. The inner shield-grid lies between the inner grid and plate while the outer surrounds the plate. They are connected together by a plate which may be seen at the left end of the outer portion of the grid. It is spot welded and acts as part of the shield. The shield is biased positively when operating under the shield-grid method, while with the space-charge method it serves as the control member.

nor bulky and one may just as well use a somewhat simpler and cheaper tubes, omit a few things from the circuit and add 40c worth of B battery. Of course as a stunt it is interesting to do the thing and one may with careful handling even make the tube detect or amplify with no plate voltage except that obtained from the A battery by returning the plate circuit to "plus A." If anyone is sufficiently interested to try the arrangement a reading of the last year's radio literature will produce various ingenious circuits for the purpose.

SEPARATE USES OF THE TWO GRIDS

The tube in which the two grids are used for separate purposes is rather obvious, and incidentally the 222 is not especially aimed at that purpose and not especially good for it. The combinations that one can think of readily are—

Reflex systems with one grid for r.f. and the other a.f. Reflex systems with one grid for detection and the other for r.f.

Neutralized r.f. stage with the extra grid used for the neutralizing feedback.

Examination of these uses seems to suggest that they, too, are more interesting than useful, though there is no intention to suggest that there is no room for experiment and study.

THE SHIELD-GRID TUBE

Elsewhere in this issue the theoretical basis of shield-grid r.f. amplification is discussed at some length. It is accordingly not necessary here to go into detail and it suffices to say that the use of the UX-222 as a shield-grid tube offers for us the finest advantages we may expect from the tube in reception, and transmission—and both for the same reason, namely that this type of tube at last offers an escape from the ancient bugbear of plate-grid capacity inside the tube.

The importance of this can hardly be over-emphasized for at once we have offered us—

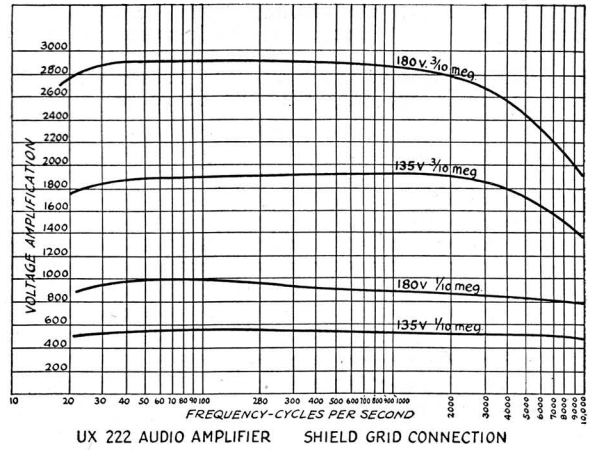
Very large gains per stage of r.f. amplification.

Freedom from the necessity of neutralizing.

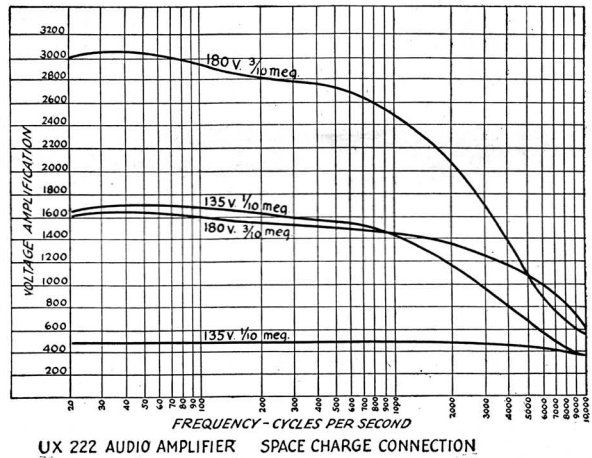
The ability to amplify successfully at wavelengths as low as 3 meters.

Oscillators relatively free from variations caused by tube heating and tube vibration, and effects caused by voltage changes.

Very large gain per stage of a.f. Amplification.



UX 222 AUDIO AMPLIFIER SHIELD GRID CONNECTION



UX 222 AUDIO AMPLIFIER SPACE CHARGE CONNECTION

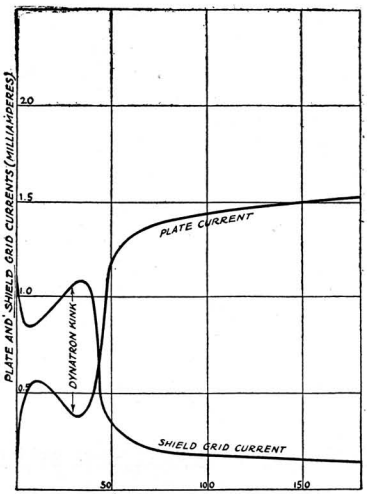
FIGURE 6.

Audio amplification obtained from two stages of 222 plus 1 stage of 371, all resistance coupled under the following conditions:

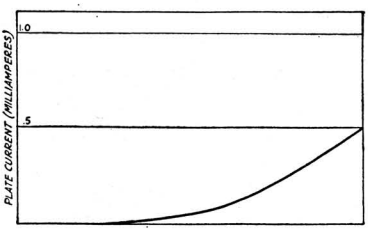
Plate load resistance for the 371 tube 2500 ohms.
Plate coupling resistors for 222 tubes changed as indicated on curves.
Plate voltages for all tubes changed as indicated on curves, bias of 371 changed from 27 to 40.5 to correspond.
Coupling Capacities in all cases .015 μfd and leaks 5 megohms.
Other conditions for shield-grid method.
Shield grid voltage + 22.5
Inner (control) grid bias — 1.5 volts

NON-NEUTRALIZED R. F. AMPLIFIERS

Elsewhere in this issue there are shown two receiving sets using a stage of 222 for r.f. amplification ahead of the detector. Either of them can be made to operate in the broadcast or other wavebands by simply changing the tuning coils and condensers. The theoretical background of these sets is discussed in a separate article and will not be taken up here except only to point out that whereas there is



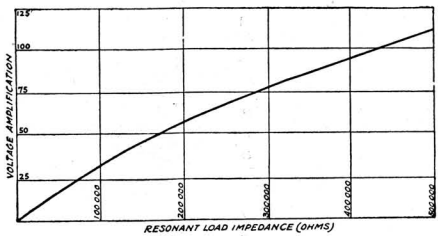
UX 222 SHIELD-GRID CONNECTION. EFFECT OF PLATE VOLTAGE WHEN CONTROL (INNER) GRID VOLTAGE = −1.5 SHIELD (OUTER) GRID VOLTAGE = +45



UX 222 SPACE CHARGE CONNECTION EFFECT OF PLATE VOLTAGE WHEN SPACE CHARGE (INNER) GRID VOLTAGE = +22.5 CONTROL (OUTER) GRID VOLTAGE = −1.5

some question as to the usefulness of such terrific amplifications in 3 stages of broadcast-wave amplifier (200- to 600-meter region) there is no question at all as to the desirability of a very great increase in sharpness and sensitivity in *one* stage of amplification at the short waves, and especially in amateur telegraphic and telephone work.

The biggest difficulty has been that the 301-A type of tube was not suited to short-wave r.f. and we had no means of bringing up the signal level except by using a larger antenna or coupling closer to the old antenna, the effect in both cases being to bring the noise up with the signal—making a net gain of 0 as far as readability went.



UX 222 SHIELD-GRID CONNECTION. EFFECT OF IMPEDANCE OF RESONANT LOAD ON VOLTAGE AMPLIFICATION WHEN
PLATE VOLTAGE = +135
OUTER (SHIELD) GRID VOLTS = +45
INNER (CONTROL) GRID VOLTS = −1.5

Now, however, we have an r.f. amplifier tube that is actually effective at all wavelengths above about 3 meters and therefore we are able to amplify the desired signal while at the same time the selectivity of the amplifier prevents the surrounding "background" from coming up with the signal. In a clear receiving point this is not fully appeciated—in a noisy one it is a godsend.

SHIELDING

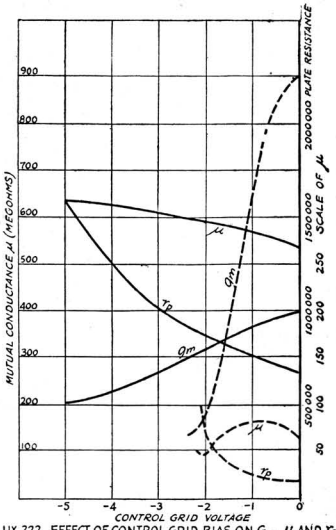
As will be seen from the description of the tuners made by Messrs. Westman and Bourne, it is not sufficient to shield *inside* the tube, we must also shield the input circuit from the output circuit—and this holds at all wavelengths if the most is to be gotten from the tube. Feedback through the batteries must also be prevented, either by filters as in Bourne's receivers or by the use of separate batteries as in Westman's and in the crude affair used by the writer. Without these precautions the full beauty of the shielded-plate method of operation (which is of course another way of saying shield-grid) cannot be appreciated.

SUPERHETERODYNE WORK

It was suggested above that the tube works at all wavelengths. This of course includes the "intermediate frequency" region in which the superheterodyne amplifiers work. Since the possible voltage gain of one stage of 222 is so large there seems an excellent chance that a single stage of such i.f. will out-perform the usual 2- or 3-stage affair. One or possibly two receivers of this sort will be described later. Various combinations are possible and these will be considered at that time.

OSCILLATORS

As we all are only too well aware our big difficulty in making oscillators operate at constant wavelength is that the tuned circuit does not entirely fix the frequency.



UX 222 EFFECT OF CONTROL GRID BIAS ON G_m, μ AND r_p FOR BOTH SHIELD-GRID AND SPACE-CHARGE METHODS OF OPERATION, THE CONTROL GRID IN EACH CASE BEING THE ONE APPROPRIATE FOR THE METHOD.

CONDITIONS---

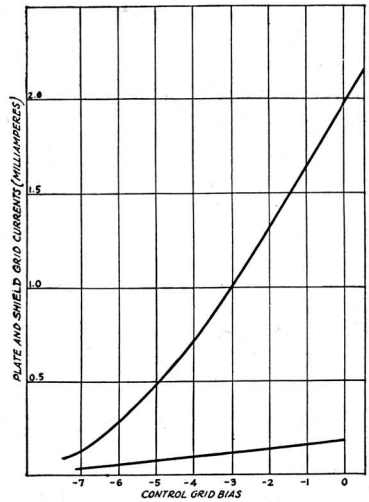
SHIELD GRID METHOD	SPACE CHARGE METHOD
PLATE VOLTAGE +135	PLATE VOLTAGE +135
SHIELD VOLTAGE +45	INNER GRID VOLTS +22.5

THE DASHED CURVES APPLY TO THE SPACE-CHARGE METHOD.

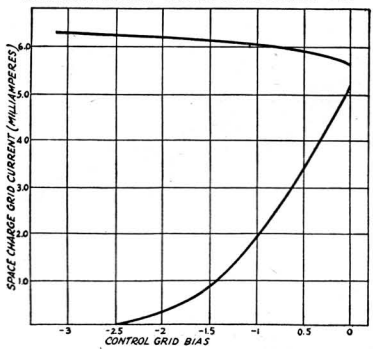
We come fairly close to it sometimes by running the tube cool and using a large capacity and a low-resistance coil but we never quite hit the thing at the shorter waves unless crystal control is resorted to. The reason is that the tube capacity insists upon working its way into the argument and upsetting things. The most troublesome of these possible tube capacities is the plate-grid one which permits feedback through the tube. The forcible removal of this feedback by the introduction of the shield grid leaves us in a more favorable position for providing our feedbacks by external means that are under better control with a possibility of smoother and steadier operation. This is a subject in itself and more will be said of it later. The 222 is of course a small tube and with it nothing more than experimental work may be done but perhaps that is not the end of the story and we may in the end have not only laboratory oscillators but actual transmitting oscillators which are somewhat more free from the undesired effects spoken of.

THE PLIODYNATRON

One type of oscillator which is possible with the 222 may be of considerable use for laboratory work at least. This is a sort of oscillator which does not use the ordinary principle of feedback from plate to grid but instead takes advantage of a very curious reverse-current effect caused by "secondary emission" from the plate. This effect is shown in one of the curves herewith and is explained in the article on the use of shield-grid tubes as r.f. amplifiers. Just now we are interested in it from the stand-



UX 222 SHIELD GRID CONNECTION EFFECT OF CONTROL GRID BIAS ON PLATE CURRENT AND SHIELD GRID CURRENT WHEN PLATE VOLTAGE = +135 AND SHIELD VOLTAGE = +45

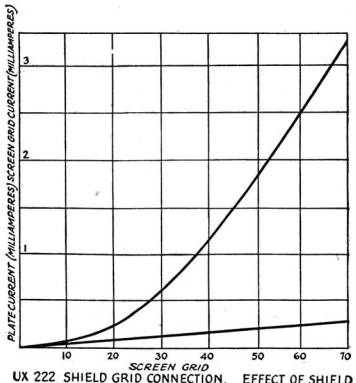


UX 222 SPACE-CHARGE CONNECTION EFFECT OF CONTROL GRID BIAS ON PLATE CURRENT SPACE-CHARGE GRID CURRENT WHEN PLATE VOLTAGE = +135 SPACE CHARGE (INNER) GRID = +22.5

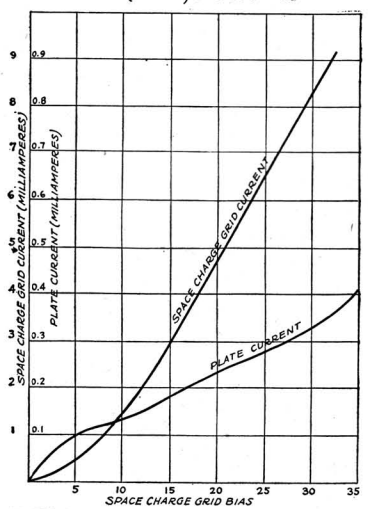
point that any tube or arc curve with such a kink in it can be used to produce oscillations in a tuned circuit associated with the device. The tube and the circuit can be connected in several ways and it suffices now to say that the advantage of the affair would be the use of untapped coils without ticklers and tuned by a single condenser. It is hoped that we will be able to describe such a device later and it therefore need not be discussed here in detail.

TRANSMITTING AMPLIFIERS

What has already been said with regard to r.f. amplification must make one think how nice it would be to have a big brother of the 222 as an amplifier for transmission. One could then get large amplifications in a single stage, and with reasonably careful screening could work without frequency doubling while at the same time being reasonably sure that the oscillator would proceed steadily though the antenna was



UX 222 SHIELD GRID CONNECTION. EFFECT OF SHIELD GRID BIAS WHEN PLATE VOLTAGE = +135
INNER (CONTROL) GRID BIAS = −1.5



UX 222 SPACE-CHARGE CONNECTION. EFFECT OF INNER (SPACE CHARGE) WHEN PLATE VOLTAGE = +135
OUTER (CONTROL) GRID VOLTAGE = −1.5

swinging, or the plate voltage of the amplifier changing. The main advantage would seemingly be that one might expect to operate a reasonably large amplifier by an oscillator small enough to be battery-driven. Note however that the curves of the 222 (plate voltage against plate current) show an increase of only 7% (1/10 mil.) in plate current when the plate voltage is changed from 85 to 160. Compare this with an increase of 170% (9.5 mils.) for the 301-A tube. Thus a bad ripple in the plate supply (poor B sub) should not bother the 222 greatly while its transmitting "big brother" should be able to operate decently in the face of a poor plate supply filter or bad regulation of plate voltage—or perhaps even the effect of key thumps.

This has, as was suggested at the start, been a most hasty and general discussion. That it has been possible to cover the subject even in part is due to the coöperation of several of our good friends in the League and of Mr. Harold Westman of this staff.

Corrections on International Test Results

SINCE the results of the International Relay Party appeared in *QST*, the following changes and additions have been made in the list of certificate winners: With 40 points, svAYRE becomes OFCS for Venezuela; ep3FZ wins in Portugal with 11 points; and sa FC6 gets the certificate for Argentina with 24 points. It is unfortunate that an error was made in naming oz2AC as winner in New Zealand with 72 points. Oz3AR, whose report arrived after the article was printed, shows a total score of 88 points, which has been checked and found to be correct. This therefore means that 3AR receives the certificate for New Zealand instead of 2AC.

On the American end of things, further reports have necessitated two changes. It develops that 7DF tied 6AM with his one point for China, and nc5AJ with his one point for New Caledonia. This means that in spite of the announcement previously made, no certificate can be awarded for either of these two countries. We are sorry that these changes are necessary, but it appears that 7DF's first report was lost in the mails, so that we had no record of his scores until now.

—*L. A. J.*

A HAM SANDWICH