Dealing With Amplifier Distortion

A Talk About the Causes

By "Megohm"

SEVERAL correspondents complain of "blasting" and distortion of the output of their receivers, situated a considerable distance from 2YA. This is usually a matter between the last audio valve and the loudspeaker, and without actually hearing their performance it is difficult to say whether one or both is to blame. Every outfit has its limit as to the amount of undistorted volume that it can deliver, and listeners very frequently like to obtain the greatest amount of volume possible from their set. With no reserve of volume whatever, it is a sure thing that blasting will occur just as soon as a speaker gets "worked up," or a band or orchestra arrives at a double-forte passage. Distortion may be noticed just as much on high notes as on low ones, and however low an impedance valve may be employed in the last stage, if volume is being taken without any reserve, blasting or distortion is certain on passages above the average intensity.

If a cone speaker has a "papery" sound, it is not the fault of the cone, but a sure sign that the last valve is overloaded, and the cone enthusiastically responds to the high notes introduced by the overloaded valve. These high notes would be suppressed by a horn speaker. The installation of a power-valve will effect a cure.

Our ears get very insensitive on the very high and low notes, so that unless these are much amplified we do not appreciate them. It is the fault of most amplifying systems that they amplify the central portion of the musical scale quite well, but, according to the particular system employed, they fall off more or less badly on the extremes. And we must drag the loudspeaker into this argument too, for it will not always reproduce perfectly good extreme notes that are put out by the last valve.

Weakness of High Notes.

VERY high musical notes are inclined to be weak when reproduced, partly because they have not been amplified to the same extent as the body of the piece, and partly because the speaker passes them on weakened, or even distorted. This action is noticeable on high violin or piano notes, and whistling. If your outfit reproduces these with volume somewhat proportioned to the whole, then that is good. But the insensitiveness of the ear also creeps in here, and although there may be fair amplification of these high notes, unless it is exaggerated we may only hear them weakly. We distinguish one instrument from another by the overtones or harmonics produced with the fundamental or actual note, and when we get high in the scale we are unable to tell whether we can hear these harmonics or not, and that has a deal to do with the weakness of high notes, and the difficulty sometimes experienced of discriminating between high piano notes and those of a piccolo or a xylophone.

Results on Low Notes.

WHEN we come to the low notes conditions are very similar, though in some ways more difficult. As the ear loses its sensitivity on the low notes, it takes a tremendous amount of energy to make the ear appreciate the sound, and this energy causes a heavy tax on the capabilities of the amplifier and speaker, so that in descending we arrive at a point where it is decided that the "game is not worth the candle," or that it is not worth the expense and bulk of supplying an amplifier that will serve to make properly audible any notes below this point. Our amplifier and speaker, a cone, may be amplifying tolerably well down to 100 or even 80 cycles, but below that it will be attempting to amplify notes, but only producing muffled sound with distortion. The broadcast station may settle the matter for us and decide to cut off at, say 60 cycles, so that if we can bring about some improvement in our lower note amplification, we shall get all there is to get, though in practice the transmitter will be likely to be putting out notes of a lower audio frequency than a receiver is likely to reproduce. And if any transmitter were changed to send out no frequencies below 100, probably a large number of listeners with reproducers weak on the low notes would notice an actual improvement in their reproduction.

Quality of Musical Harmonics.

BUT this cutting off of low frequencies must not be overdone at the transmitter, because although a horn speaker of a certain type may not be able to reproduce such sounds at their actual pitch, it can lead you to believe that it is doing so in this way. Musical sounds are rich in harmonics, as already mentioned, and these give the instrumental quality to the sound. These harmonics, several in number, are all higher than the fundamental note. When a low note comes through a small horn speaker, the latter is probably quite unable to reproduce this note, with a frequency of, say, 60 cycles. If harmonics did not accompany the sound, it is quite likely that nothing of this note would be heard behind the melody. But the horn is able to mislead us by reproducing the harmonics down to the lowest one that it is capable of passing on, and quite likely the lowest one will be somewhat muffled or distorted, Listening to a horn speaker by itself, it is difficult for even a musical ear to decide just what lower notes are being suppressed, owing to the reproduction of their "ghosts" or harmonics, which may easily be considered to be the fundamentals. The only way to realise the difference of reproduction is to sit between an ordinary horn speaker and a cone that emphasises the lower notes. This has been done by the writer, and is a highly interesting study.

Two Loudspeakers Used.

FOR several years the Zenith Company of Chicago has supplied two loudspeakers, a cone and a horn, in all its cabinet sets, and some time ago, as already mentioned in this column, the writer adopted this idea. With the two speakers connected in parallel, and with a good choke filter in the circuit, the tendency for speaker overloading is very greatly reduced, and a much more faithful rendering of the studio items is obtained. But in this method there was still the attempt of the horn speaker to reproduce notes below its ability, and to distort them in the process. As the principle of utilising two speakers is for the horn to take care of the high frequencies and the cone the low ones, it was decided that any attempt on the part of the horn to deal with low frequencies must be suppressed, and this was accomplished by placing a fixed condenser of, say, .005 or .01 capacity in series with one of the speaker leads. The result was a considerable improvement in tone, any tendency to "mushiness" on low notes being cut out. The exact value of condenser must be found by trial, but if too small it will cut out at too high a position on the scale. It is not suggested that every horn speaker used with a cone should be fitted with a series condenser, but the idea is put forward for the experimenter who is continually striving to improve the quality of musical reproduction and speech too, and who is not prepared to sit back and say that his reproduction is "perfect." It may seem a large outlay to many to run two speakers, but it goes a long way towards settling a vexed question. After all, those who have run one speaker for a time and increased the output of their set can help quality reproduction in a way that is probably impossible with any internal alteration of components by purchasing a speaker of the opposite type to the one they already possess. An output filter or transformer is of course essential, and after these improvements have been carried out, further refinements may be gradually carried out in the hook-up. A resistance unit is easily tried in place of a transformer. This idea of two speakers has already been dealt with by the writer, but is good enough to be repeated.

The Effect of Power Valves.

IN the matter of valves, all set-owners have a free hand, so far as the last audio valve is concerned, with the reservation that where dry B batteries are employed the power-valve in the last stage will be limited to a reasonable plate current, in order not to put too much of a drain on the battery. Where a B accumulator or eliminator is in use the consideration of plate current is practically negligible. In such case, if the last audio valve is, say, a 112, and is overloaded, then the substitution of a 171 will effect a great improvement, but the appropriate grid-bias must be provided and kept near the correct voltage by occasionally testing the dry C battery with a voltmeter. Then, as a last resort, there is the 210 type of power-valve, which will handle big volume, but takes from 6 to 7½ volts and 1.1 to 1.25 amps on the filament, and works best on a plate voltage of 200 to 400, taking up to 22 milliamps. This last-mentioned valve, it will be seen, is essentially one for operation from a B eliminator giving high voltage, and where a transformer winding is available for heating the filament, thus saving the necessity for extra A battery voltage to run the valve at its best output.

It should be noted that no receiver giving loudspeaker volume, and employing a 201A tube as the last audio amplifier, is capable of quality reproduction, as there is sure to be overloading and distortion. Receivers giving distorted output will usually be improved by changing the last valve for one capable of handling the volume without distortion. For a 201A a 112 may be substituted, for 112 a 171, and for 171 a 210, but the latter only if high plate voltage is available. At 135 volts on the plate the 112 requires the same grid bias (9 volts) as the 201A, but takes 6 milliamps instead of 2.5 on the plate.

This may be economically run from a dry B battery of not too small dimensions, and the writer knows that some listeners are running 20 milliamp valves off dry batteries of ample proportions, and, needless to say, are getting good results, though the batteries will not last the same time as when running a set with a total plate current of 8 to 10 milliamps.

If you wish to step up from the 112, then the 171 is available. This valve will take a plate voltage up to 180 volts, which requires the high grid bias of 40½ volts, and passes 20 milliamps. At 135 volts on the plate the grid bias is 27 volts, and plate current 16 milliamps. The filaments of the above valves all run off a 6-volt accumulator, but the correct voltage at the filament terminals of the valve-holder is 5 volts. The UX120 is only a semi-power valve, and will not carry any great volume. The filament requires a 4-volt battery, or 4½ volts, 3 dry cells, for which use it is most suited. Plate voltage runs up to 135, 6.5 milliamps being passed.

Gradual Distortion May Creep In

THE most troublesome form of distortion is that which gradually creeps in. When the set is first installed reproduction may be amazingly good, and yet quality will gradually fall off week by week in such a way that it is not noticed by the listener, until it at last gets obtrusive and calls for attention. It is very easy to forget about amplifier valves, yet they may have gone off to such an extent that their emission has fallen much below the point where they can carry the low audio frequencies without distortion. With an eliminator the deterioration of the rectifying valve may be reducing plate current, or a dry B battery may have parted with its quota of milliamps and have a residual voltage not worth consideration. Then there is the grid-bias battery, so easily neglected, yet so important where quality is sought.

It is important to tune in the dials to the exact maximum reading, and reduce volume by other means than detuning with the dials, which may easily introduce distortion. Dimming the R.F. filaments is one of the best means of volume control, which has the advantage of preventing the detector from being overloaded.

THERE are many other sources of distortion, but those connected with the last valve and the loudspeaker are the most common, and are at the present time causing anxiety to a number of listeners, which is the reason for this article, which contains much that is not new, but will, it is hoped, be helpful to those suffering distorted reception.

ACTION OF THE SCREEN-GRID

THE UX 222 VALVE

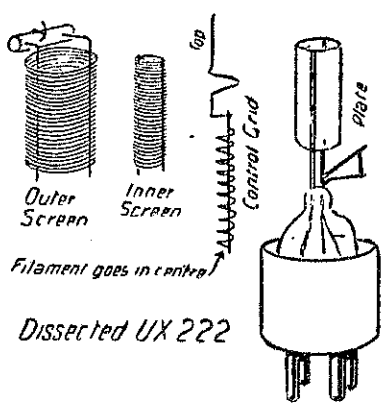
(By "Megohm.")

THE construction of the UX222 screen-grid valve is fairly complex in comparison with the ordinary receiving valve. The extra grid consists of two circular screens of wire, one encircling the outside of the plate, the other inside the plate, between the latter and the ordinary control grid, the lead for which comes out at the top of the valve. In the very centre of all is the filament. The two screen-grids are connected together, and the lead brought out to the ordinary grid connection of the valve base.

The sensitivity of the control exerted by the grid (and hence the amplifying value of the valve) is definitely limited by the cloud of electrons surrounding the filament. If an extra grid is interposed between the filament and the regular control-grid, and charged positively, it will, by virtue of its proximity to the filament, break up the cloud and increase the control range of the regular grid.

The extra grid may also be located between the control-grid and the plate. Here it will require a higher positive charge than before, but it now also serves another purpose—namely, to reduce the troublesome capacity effect between the grid and plate. It acts as an earthed centre plate, splitting the "fixed condenser" formed by the grid and plate into two smaller condensers in series.

As already mentioned, the outer screen encircles the plate completely. The inner section acts both as a space-charge disrupter and as a capacity re-



ducer, while the outer section (which has nothing to do with the stream electrons, because they stop at the plate), serves merely to reduce the capacity between the outside of the plate and the connecting leads, etc. It should be noted that the inner screen-grid is chiefly concerned in the following remarks.

The "space-charge" spoken of is the negative charge of the cloud of electrons hovering round the filament, and which have been unable to travel to the plate through being insufficiently heated, and so having too low a velocity, and therefore easily retarded by the space-charge. Increased plate voltage decreases the space-charge, which means that more electrons reach the plate. As the control grid is nearer to the space-charge than is the plate, variation in the grid voltage has a greater effect, in proportion, than changes in plate voltage, so that small grid voltage variations make large plate-current variations, which gives the amplifying effect.

Now, this space-charge is actually detrimental to the working of the tube, and the cause of its low efficiency, because its repelling effect is added to the repelling effect of the grid, and so any change in the repelling potential of the grid is only a partial change in the whole repelling potential. If we could wipe out the space-charge altogether, and leave the grid with the only negative charge, then grid variations would have a much greater percentage effect upon the whole negative charge, and the amplification factor would at once rise from 6 or 8 to perhaps 30. This because the change in repelling effect of the grid is complete in itself, and no energy is wasted in "gingering up" the drowsy encumbrance known as the "space-charge," which has now been cut out by the interposition of the positively-charged extra grid between the plate and grid.

In ordinary valves, 85 per cent. of the plate voltage is used in overcoming the space-charge, and the remaining 15 per cent. in establishing plate current, so that by removing the space-charge the 85 per cent. of high-tension voltage needed to overcome it may be in future saved, and the valve will operate with only the 15 per cent. required to establish current through the valve. This means that where 100 volts was formerly applied to the plate, with the screen-grid 15 volts, would give an equal result. On the other hand, instead of thus reducing plate voltage, and getting equal results, we may in practice keep the plate voltage as before, and thus obtain increased amplification from the greater electron stream from filament to plate that is affected by the grid voltage variations.

It is by placing a positive charge at the point where the negative charge accumulates that the extra (inner) grid obliterates the space-charge. The extra grid is really doing part of the work of the plate, but by its position near to the source of the trouble it is able to do this part of the work more efficiently than the plate can.

This is a brief description of the two main points in the action of the new valve.

TIPS AND JOTTINGS

(By "Megohm.")

A CORRECTION.

In a recent article on two-valve amplifier a misprint caused "2 inches" to appear as the diameter of the tuning-coil for the crystal. Further down the same page, however, the correct diameter, 3 inches, was mentioned.

B ELIMINATOR SUCCESSES.

SINCE publishing the success of a Christchurch constructor of the "Record" B eliminator, we hear of several others that have been running satisfactorily for some time. Naturally many constructors will not think of sending in a report of their success, but the writer is just as pleased to hear of such as he is to help any constructor who is confronted by a difficulty.

GLOW-TUBE EXTRAVAGANCE.

THE use of a "glow tube" regulator in B eliminators sometimes improves the stability of the R.F. circuit, and reduces the tendency to "motor-boating" and oscillation on the audio side, but unless the eliminator will give an extra 30 milliamps without too much of a drop in voltage, the "glow tube" should not be used. Such regulation is therefore only attained at the expense of a heavy drain on the eliminator output.

A CARTRIDGE CHARGER WARNING

LISTENERS who have employed a bulb rectifier battery charger always connected to the battery so that switching on the current to the charger would set the battery charging, must remember that if they change over to a Raytheon A charger, they must provide a switch to open the charger circuit. The cartridge rectifier may allow a drain of as much as 180 milliamps to pass if left connected to the battery when not charging, and this leakage will run down an A battery in two or three days. A d.p.d.t. switch to throw over for set or charger is the best arrangement.

THE LOUDSPEAKER POSITION.

COMMENTING on the excellence of the few loudspeakers, and the need for improvement in the many, "Radio Broadcast" says: "It is our opinion that improving the loudspeaker will spell trouble for the designers, manufacturers, and owners of a.c. sets. With a Balsa (wood diaphragm) loudspeaker which we operate with a Western Electric 540-AW unit out of a single 171 tube with about 160 volts on the plate, the average a.c. set is too noisy for pleasure, although on other loud speakers the hum is inaudible. In other words, the a.c. tube either marks the limit of loudspeaker development, or the newer and better loudspeakers will force a.c. tubes to deliver signals unruffled by a.c. hum. We hope the latter, for the average loudspeaker of to-day is less than 5 per cent. efficient, considering the entire audio band to be passed."