The Screen Grid and the Pentode

A Comparison and Contrast

THE present age in wireless development may be called the age of the multi-electrode valves. The advantages of this type of valve was first demonstrated by the three-electrode valve with which, today, every owner of a valve set is conversant. This was in turn followed, but in no means replaced by the double grid valves to which we have given a little space in recent issues. Now every wireless enthusiast speaks in terms doubtful of concise of the tetrode valves, the screen grid and the pentode. To the former class the accompanying article by R.W.H., a writer to "World Radio," will be of no mean interest.

WE HAVE been familiar for some time now with two entirely different kinds of four-electrode valves, each of which contains filament, plate, control grid, and an extra grid.

In the first of these four-electrode valves to be developed the additional grid is placed between the filament and the grid used for control purposes. The task set it and the way in which it functions are both exceedingly interesting. The attraction exercised upon electrons by positive ions (that is atoms which contain one or more electrons less than their full complement) is a force far greater than that of gravity. It is this force which draws electrons emitted by the filament, through the intervening vacuum within the valve, to the plate. But another influence is also at work; electrons repel one another with a force that is also far greater than gravity.

Consider what happens in the neighbourhood of the filament when the three-electrode valve is working. A cloud of electrons is ejected and the pull exercised by its positive potential draws them towards the plate. But electrons that are just leaving the filament are, so to speak, dammed back by the repulsive force of those which left a tiny fraction of a second earlier.

Each electron is thus subjected to what we may term a backward thrust from those in front of it and a forward thrust from those behind as well as lateral thrusts from those all round, and itself exercises similar thrusts to its neighbours. The net result is that we have in the neighbourhood of the filament a tremendous congestion of electrons, which is known as the space charge.

To overcome this to some extent a high positive potential must be applied to the plate, and even so the electron stream is not so rich as it might be.

The inner grid of the four-electrode valve arranged between the filament and the control grid is kept at a small positive potential. Since it is immersed in the space charge it exerts a very powerful pull upon electrons that have left the filament. As these approach it they feel the pull of the plate; they rush through its meshes and those of the control grid to arrive at the plate. The congestion round the filament is greatly reduced and a smaller plate voltage suffices to maintain the required stream.

High Magnification.

THE second type of four-electrode valve is of particular interest to the long-distance man, since it enables a degree of magnification previously only dreamt of to be obtained with perfect stability.

In the three-electrode valve the capacity between the grid and the plate leads to unwanted feed-back effects. Energy from the plate circuit travels back to the grid circuit through the tiny condenser formed by these two electrodes. Thus, if we try to obtain big amplification by using highly efficient coils and variable condensers in the two circuits, we find that as resonance is approached signal strength builds up rapidly until at a point a good deal short of the amplification theoretically obtainable the valve suddenly bursts into oscillation.

In the screened-grid valve plate-grid capacity is reduced to something so small that its effects, provided that the lay-out and wiring are suitable, are almost negligible. Between the control grid and the plate a screening grid is introduced. This is kept at a fairly high positive potential. It acts as a capacity screen between the two electrodes, preventing feed-back from occurring. Its presence has also another important effect: a very high amplification factor can be obtained in the screened-grid valve, an overall magnification of 30 or 40 from each H.F. stage being obtainable upon such wavelengths as those on the broadcast band.

Curious Effects.

THE four-electrode screened grid valve, however, has one peculiar quality which renders it unsuitable for low-frequency work.

Let us see what happens when the plate voltage is something less than that of the screen. Electrons from the filament, travelling at terrific speed, pass through control and screen grids, reaching the plate. Such is their velocity that the force of their impact upon the plate drives out other electrons, which travel with a smaller velocity away from the plate. Under the influence of its pull these are attracted to the screen grid. It follows that the plate current falls short of what it should be.

A still more curious effect results if we gradually increase the plate voltage: we find that as we do so the plate current does not rise, but *falls*. Owing to the increased electron speed the number driven out from the plate and "mopped up" by the screen increases. This fall in current continues until a point is reached at which the plate potential is only a little less than that of the screen. If we now make the plate gradually more and more positive current rises sharply.

Plotting the results obtained as a curve, we find that we have something not unlike a capital "N," the third stroke being very long and curving off towards the right until it becomes almost horizontal.

On the low-frequency side of the set the voltage changes in the plate circuit may be quite big; hence a valve with such a kinky curve is incapable of providing a large undistorted output. Until something was done to straighten out the curve practically no use could be made of the screen-grid valve's wonderful amplifying powers before note-magnification.

The Pentode.

HOW was the problem to be tackled? A solution was found in a highly ingenious way by the addition of a third grid.

In the pentode, or five-electrode valve, designed for low-frequency purposes, this is placed between the screening grid and the plate. It is connected within the bulb to the mid-point of the filament and is thus strongly negative in comparison with the plate.

Now let us see what happens in the pentode valve. Electrons leave the filament at very high velocity under the influence of the pull of the plate. So great is their speed that they travel through the control grid, the positively charged screen, and the auxiliary grid, whose potential is only a little above zero. On reaching the plate the force with which they collide with its surface drives out other electrons in the way previously described. These leave the plate with a much lower velocity, and they have not journeyed far before they experience the repulsive force exercised by the auxiliary grid because of the presence of electrons upon it.

Owing to their low speed this repulsive force suffices to drive them back again to the plate and to prevent them from escaping to the screen. The auxiliary grid, in fact, acts as a kind of shepherd, heading off would-be wanderers and ensuring their return to the fold. Its effect upon the valve's performances is that the curve is no longer kinky. As the plate voltage is raised the plate current increases until a point is reached at which no raising of the former produces any appreciable increase in the latter.

A "Hexode" Next?

IN its present form the pentode is an output valve with an amplification factor in the neighbourhood of 60. It is not yet capable of handling a very large input, for which reason it cannot be used successfully as the second of two note-magnifying stages in an ordinary receiving set. Where, however, signals of telephone strength are obtainable without any note-magnification a single pentode stage following the rectifier will enable reasonable loudspeaker volume to be obtained. The advantages of using a single pentode stage will be appreciated by the shortwave enthusiast who has probably realised from experience how difficult it is to obtain thoroughly satisfactory working from two efficient note-magnifying stages in cascade in a receiver intended for very high frequencies.

Further developments are promised and it is likely that we shall see in the near future pentodes suitable for other positions in the receiving set. Time may even bring forth a hexode valve with four grids, the first immersed in the space charge, the second acting as control grid, the third functioning as a screen, and the fourth carrying out the shepherding duties which have been described.

The Telescope of Theology

Someone has likened theology to a telescope. It is meant to give you a clearer view of things, but each one wastes time by boasting about his own telescope; one, that his is the oldest, handed down from apostolic times; another, that his is the latest, up-to-date with modern learning. If only we would think, we should see that we were looking at the telescope instead of through it. No wonder we go back from our worship to our work without a glimpse of the Way, the Truth, and the Life. We are of no use to the outside world. It says, "We don't care a bit about the date of your telescope, but we should be very grateful to you if, as we go into another week of life with its duties and temptations, you could show us something to lift up our hearts and make us want to be better men and women than we often are." —The Rev. Arthur Gilbertson, R.N., Plymouth.