Power Valve Output

Intricate Calculation Explained

"BY CATHODE"

A NUMBER of the queries with which our Technical Editor was confronted at the Auckland Radio Exhibition were concerned with the output of power valves singly, in parallel, and in push-pull. The magnitude of the ground opened up for discussion rendered it inadvisable to go into the matter very fully on the spot, so "Cathode" has been instructed to cover the subject fairly completely in the present paper, some effort being made also to answer certain specific queries raised by our enthusiastic Auckland readers.

It will be necessary to deal with parallel and push-pull connected valves separately from the main issue; the pentode will also demand separate mention, since the conditions governing its use differ considerably from those encountered in normal practice with the triode.

The only method of calculating undistorted power output which has any pretensions to accuracy involves the insertion of a "load line" across a family of plate voltage-plate current curves. It must be understood that the limiting factor in determining the possible output from a power valve (apart from the obvious limitations of plate voltage and anode dissipation) is the necessity of keeping second harmonic distortion within reasonable limits; the permissible second-harmonic distortion is usually taken as 5 per cent., and the term "undistorted output" is interpreted as covering a second-harmonic distortion not greater than this percentage. In case the term "second-harmonic distortion" may not be familiar, it may be explained that the operation of an amplifying valve on a portion of its characteristic which is not strictly linear (i.e., down towards the "bottom bend") results in the generation of an additional frequency twice that of the fundamental or applied frequency. A small percentage of distortion of this type can be readily tolerated, but beyond a certain point, the effect on the output becomes very distressing.

Valve manufacturers generally specify the limits within which particular types of valves must be worked, either by stating the maximum permissible plate dissipation and voltage or, more tactfully, by recommending a certain bias for a certain plate voltage. In the latter case, it can usually be taken for granted that the manufacturer has been at some pains to ascertain the best operating conditions to suit the average loudspeaker, and this permits a simplified method of ascertaining the approximate maximum output, a few words will be devoted to this approximation a little later on.

THE reader is requested to examine first of all the family of grid-volts anode-current curves in Fig. 1. The method of taking these curves is doubtless familiar to most readers, so that it is unnecessary to go through any explanatory process here. Similar curves are usually supplied with purchased power valves. It is possible to draw on a diagram such as this a line corresponding roughly to the path traced by the changing anode current with a given load (such as a loudspeaker might comprise) in the anode circuit. Such a line is usually termed a "dynamic curve," although, in point of fact, any appreciable curvature is a thing to be avoided. Strictly speaking, it is incorrect to depict the path traced by the changing plate current by a single line, since the load in the plate circuit is in practice usually indicative as well as resistive, with the result that the current, "lagging" as it does behind the voltage, traces out an ellipse. However, this ellipse would be different in shape and dimensions for every applied frequency so that for convenience it is usual to assume purely resistive load, and this assumption does not lead to any serious error.

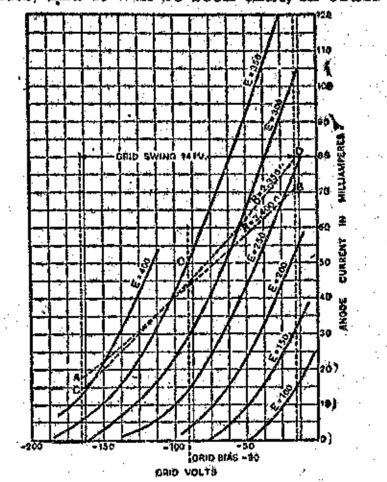
The insertion of a "load line" or dynamic curve becomes very much simpler if, in place of grid-volts anode-current curves, use is made of anode-voltage anode-current curves. A family of such curves is shown in Fig. 2, together with dynamic curves for two different values of load resistance.

The insertion of the load line or dynamic curve may be most easily effected by first taking a convenient figure for the anode voltage and calculating the resulting current through the assumed value of the resistance in the anode circuit. Thus, referring to Fig. 2, a convenient figure for calculation would be 300 (anode voltage) and, through a resistance of 6000 ohms, this would result in a current of $300 \div 6000 = .05$ amps. or 50 milliamps. A light line may then be drawn between the points marked 300 volts and 50 milliamps respectively, and this line may then be said to have a "slope" corresponding to 6000 ohms. On order to complete the "dynamic curve" it is merely necessary to draw a line parallel to that, the construction of which has just been described, this second line passing through the "operating point 0" which for the moment, we will assume to have been determined by the valve manufacturer's recommendations as to anode voltage and grid bias or anode dissipation.

So far things have been fairly simple. Before going on to matters involving a trifle more difficult in explanation, it is desired to refresh the reader's mind on one or two points concerning which he may have become a trifle hazy.

Firstly, as to permissible anode dissipation. Many power valves are supplied with a stated maximum anode dissipation; thus, the LS6A is rated to dissipate 25 watts maximum, while the P625, although no express statement is made on the point, is rated to dissipate up to 5 watts. The LS5A valve [illegible] in preparing Fig. 2 was rated at 12 watts, and it will be seen that, in order to keep the dissipation within safe limits with an anode voltage of 350, it was necessary to limit the current to $12 \div 350 = .034$ amps or 34 milliamps, this being accomplished by applying a negative grid bias of 110 volts. Had a greater anode dissipation been permissible, a greater maximum power output could have been obtained by using a less grid bias; it is not unusual to find that the steady plate current is, for greatest output, larger at, say, 300 volts than at 400.

Secondly, the reader must understand that, though the average voltage available at the anode is that provided by the source of the anode current (accumulator or mains unit) less a small drop occasioned by the resistance of the speaker or of the choke or transformer through which the anode current is supplied, the instantaneous voltage applied to the plate may be less or greater than this figure. It is not difficult to understand how the instantaneous voltage can be less than the source, because the inductive load in the anode current will present a sub-



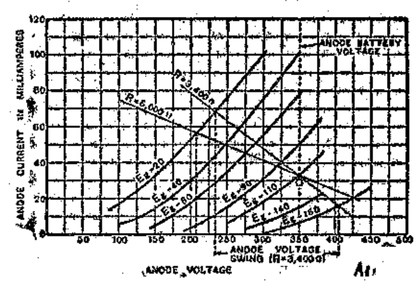


Fig. 1, Upper.
Fig. 2, Lower.