The elegant method I describe here was often used in the past and was very popular because it required no sophisticated calculations. I also provide its mathematical justification and give an example to illustrate its use.

**DESCRIPTION**

Consider the anode characteristics of a given valve, as shown in Fig. 1, on which are added:

- The bias point \( P(\text{Ip}_b, Vak) \),
- The load line \( R_{\text{load}} \) passing through the bias point,
- The points \( A \) and \( B \) on the load line, defined at the maximum sine input signal amplitude: \( \pm e_0 \),
- The points \( C \) and \( D \) on the load line, defined at the half sine input signal amplitude: \( \pm e_\frac{1}{2} \),
- The point \( M \) on the load line, defined as the middle of \( AB \).

You can then estimate the harmonic distortion using the following formulas:

\[
\%H_2 = 100 \left[ \frac{MP}{AB} \right],
\]

\[
\%H_1 = 50 \left[ \frac{AC + BD - CD}{AD + BC} \right].
\]

Higher order harmonic distortion can also be estimated using additional points on the load line. But, the accuracy of the graphical method decreases rapidly with the increasing order, making the method questionable.

The graphical method also applies to push-pull configuration of valves. In this case, curves to consider are composite characteristics.

**JUSTIFICATION OF THE METHOD**

For a given bias point \( P \) and a load line \( R_{\text{load}} \), the anode current is only a function of the input signal: \( e \).

You have: \( (\text{Ip}_b - \text{Ip}_0) = F(e) \). You can approximate this function by the following Taylor's expansion:

\[
F(e) = a_1 e + a_2 e^2 + a_3 e^3 + \cdots
\]

which, in the case of a sine input signal, \( e = e_0 \sin \omega t \), can be rewritten as the following Fourier's series: see below (1).

To evaluate the second-order harmonic distortion, you limit the Taylor's expansion to the second order:

\[
\%H_2 = 100 \left[ \frac{a_2}{2a_1} \frac{e_0}{e_0} \right].
\]

Coefficients \( a_1 \) and \( a_2 \) of the Taylor's expansion are determined using points \( A \) and \( B \) defined in the description of the method. Some simple calculations give:

\[
\%H_2 = 100 \left[ \frac{ \left( \text{Ip}_b - \text{Ip}_0 \right) - \text{Ip}_0 }{2 \text{Ip}_0} \right] = 100 \left[ \frac{MP}{AB} \right].
\]

For the evaluation of the third-order harmonic distortion, you limit the Taylor's expansion to the third order:

\[
%H_3 = 100 \left[ \frac{a_3}{4} \frac{e_0^3}{e_0^3} \right].
\]

Coefficients \( a_2 \) and \( a_3 \) of the Taylor's expansion are determined using points \( A, B, C, \) and \( D \) defined in the description of the method. Here again, some simple calculations give: see below (2).

**ILLUSTRATIVE EXAMPLE**

Consider the output power pentode type 6550 shown in Fig. 1.

<table>
<thead>
<tr>
<th>Operating conditions for this valve are</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operation</td>
</tr>
<tr>
<td>Configuration</td>
</tr>
<tr>
<td>Anode voltage</td>
</tr>
</tbody>
</table>

The author describes a graphical method to estimate the harmonic distortion produced by valves under predefined operating conditions.
Grid n° 2 voltage 250V
Grid n° 1 voltage -14V
Load resistance 1.5k

The harmonic distortion estimation for a grid swing voltage of ±14V peak-to-peak is determined as follows:

Bias point P
- Grid n° 1 voltage -14V
- Anode current 140mA
- Anode voltage 250V

Point A
- Grid n° 1 voltage 0V
- Anode current 277mA
- Anode voltage 47V

Point B
- Grid n° 1 voltage -28V
- Anode current 25mA
- Anode voltage 422V

Point C
- Grid n° 1 voltage -7V
- Anode current 215mA
- Anode voltage 140V

Point D
- Grid n° 1 voltage -21V
- Anode current 71mA
- Anode voltage 355V

\[
\text{%H}_2 = 100 \left( \frac{277 + 25}{277 - 25} \right) - 140 = 4.4\%
\]

CONCLUSION
As you can see, the graphical method introduced here is simple and accurate enough to estimate the harmonic distortion produced by valves under given operating conditions. Although

\[
\text{%H}_3 = 50 \left( \frac{(277 - 215) + (71 - 25) - (215 - 71)}{(277 - 71) + (215 - 25)} \right) = 9.1\%
\]

REFERENCE