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# GENERAL ELECTRIC
## COMPANY
## SCHENECTADY, N. Y., U. S. A.

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## DATA FOLDER No. 72174

Title Determination of Oscillator Losses

By

Electronic Tube Engg. Div.

Information prepared for

Tests made by

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Countersigned by

Date December 16, 1943



FN-460-E (11-43)

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## DETERMINATION OF OSCILLATOR LOSSES

The oscillation test specifications for some types of high vacuum tubes require that the total power output be measured. Since, in the customary production test sets only the power dissipated in a load lamp is measured, it is necessary to add to this quantity a factor that will represent the remainder of the tube output that is not actually measured. By testing a large number of tubes, it has been found that this factor is very nearly a constant value for a given oscillator and a particular tube type. It is the object of this data folder to describe methods of determining this factor.

The major components of the loss factor may be measured and added together. The method of doing this will be demonstrated by actual data taken on a Hartley oscillator used to test GL-814 tubes. A circuit diagram and photograph of this oscillator are included in this folder.

The "Q" of the coils were measured at 15 megacycles on a Boonton Q meter.

Tank coil $Q=435$ Capacitance to resonate = 41 μμf

Load coil $Q=500$ " " " = 32.8 μμf

The following tube test conditions were used:

| | | |
|---|---|---|
| $E_b=1250$ DV | $I_b=150$ DMa | $E_{c_2}=300$ DV |
| $I_{c_1}=12.5$ DMa | $E_f=10.0$ AV | $F=15$ Mc |

The average values obtained from 94 tubes were:

$I_{tank}=3.52$ AA  $I_{load}=1.25$ AA  $I_{g2}=27.0$ DMa

$E_g=152$ AV  $I_{diode}=9.7$ DMa corresponding to $W_{lamp}=115$

The R.F. currents in the tank and load coils were measured with thermocouple type meters. The grid voltage was measured with a General Radio type 726A vacuum tube voltmeter.

Loss in Tank Coil

$$R=\frac{wL}{Q}=\frac{1}{QwC}=\frac{1}{435\times2\pi\times15\times10^{6}\times41\times10^{-12}}=0.595$$

$$\text{Loss}=I^2R=(3.52)^2\,0.595=7.38\text{ watts}$$

## Loss in Load Coil

$$R = \frac{1}{QwC} = \frac{1}{500 \times 2\ \ \times 15 \times 10^{6} \times 32.8 \times 10^{-12}} = 0.647$$

$$\text{Loss} = I^{2}R = (1.25)^{2}\ 0.647 = 1.01 \text{ watt}$$

## Grid Driving Power*

$W_g = 2\ E_g\ I_c$, where
$W_g$ = driving power in watts
$E_g$ = RMS value of the alternating grid voltage
$I_c$ = direct grid current

Since $E_g$ may be measured with a vacuum tube voltmeter, this method is simple and direct. In this particular oscillator:

$$W_g = (\ 2\ )\ (152)\ (0.0125) = 2.69 \text{ watts}$$

## Loss in Measuring Circuit

In the particular oscillator used in this example a diode measuring circuit was used, as shown in the circuit diagram. The loss here will be at least

$$W = I^{2}R = (.0095)^{2}\ (11000) = 1.04 \text{ watts}$$

## Losses in Load Lamp Leads

In the 200 watt lamp used, the filament is supported by two .050" nickel leads 5½" long. One of the leads from the press to the base is .020" copper and the other is .012" nickel, both 2" long. At 15 megacycles the skin effect makes the effective resistance of these wires relatively high.

$$**R = \frac{1}{r}\ \sqrt{\frac{u\mu_o\ f}{4\pi}}$$

Use MKS System of units

u = Permeability of material
  = 60 for nickel, 1 for copper
μ = Permeability of free space
  = $4 \times 10^{-7}$ henrys/meter
  = conductivity mhos/meter
  = $\frac{1}{1.28 \times 10^{7}}$ for nickel

  = $\frac{1}{5.8 \times 10^{7}}$ for copper

f = Frequency in c.p.s.
r = Radius of conductor in meters
R = Ohms/meter

For .030" diameter nickel leads:

$$R = \frac{100}{.015 \times 2.54} \sqrt{\frac{60 \times 4\pi \times 10^{-7} \times 15 \times 10^{6}}{4\pi \times 1.28 \times 10^{7}}} = 6.95 \text{ ohms/meter}$$

$$\text{for } 7'' \; R = \frac{7}{39.37} \times 6.95 = 1.24 \text{ ohms}$$

Likewise:

R for 2" of .020" copper wire = .07 ohms
R for 2" of .012" nickel wire = 0.89 ohms
$R_{total}$ = 2.10 ohms
Watts loss = $I^2R$ = $(1.25)^2$ 2.20 = 3.44 watts

Total Losses

The sum of the various losses that have been computed may be used as the factor to be added to the load lamp output to obtain the value of total tube output. In the example shown the constant is 15.6 watts.

The factor as calculated here is conservative because circuit wiring losses and radiation have not been considered. In order not to excessively penalize the tube, the circuit should be wired with as short leads as possible and all bypassing should be done to a common point.

Measurement of Useful Power Output

The useful power output is measured by a meter in a diode circuit across the load lamp, as shown in the diagram. This arrangement must be calibrated by a phototube. A small box containing the phototube with battery, meter, and lens is very handy for this purpose. The phototube is placed near the load lamp and the lamp is then lighted by operating the oscillator, and the phototube and diode currents are noted. With the oscillator turned off, the lamp is lighted with an adjustable 60-cycle power supply to obtain the same phototube current. By measuring the power required in this manner, the diode meter may be calibrated.

Calorimetric Method of Measurement

Another method of determining losses is to measure the power dissipated in the vacuum tube by calorimetric means. A water jacket is put around the tube and the difference in temperature between the water entering and leaving is measured by a differential thermocouple or thermometers. The jacket may conveniently be made of glass and sealed at the bottom around the tube base with wax. A constant flow of water must be used. This is easily obtained by taking water by gravity feed from a container equipped with an overflow drain. The input to this reservoir should be adjusted so that the water is always at the overflow level. With the water flowing at a convenient rate, the tube is operated under static conditions. Total watts input (plate + filament + screen grid) may be plotted against temperature rise. This should give a straight line from which a factor "k" may be computed such that watts dissipated in tube = k (water flow) x (temp. rise) for the system of units employed. Since the water jacket cannot cover the base of the tube, this factor will be somewhat higher than the theoretical value. The calorimeter is now calibrated.

The tube in the water jacket can be operated in the oscillator to determine the losses. Readings are taken of total input to the tube, load lamp output, water flow rate, and temperature rise. From the calorimeter calibration, the total power dissipated in the tube may be found. The power going into circuit losses and radiation will be the difference between the total tube input and the sum of load lamp power and power dissipated in the tube.

The circuit losses are practically constant for a particular oscillator and tube type. The tube dissipation and power output at a given input will vary among tubes. Each of these two quantities in the case of the GL-814 is in the order of five times the circuit loss. The total input is about twelve times the circuit loss. By this method, the circuit loss is found by subtracting the sum of two large quantities from another large quantity to obtain a small number. Even though the accuracy of measurement of the large quantities is reasonable, the errors are effectively magnified.

The calorimetric method is of value in determining tube dissipation and measuring a loss factor as a check on the calculated loss factor.

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*H.P. Thomas "Determination of Grid Driving Power in Radio Frequency Power Amplifiers" Proc. I.R.E. vol. 21 pp 1134-1141; Aug. 1933.

**J.R. Whinnery "Skin Effect Formulas" Electronics, Feb. 1942

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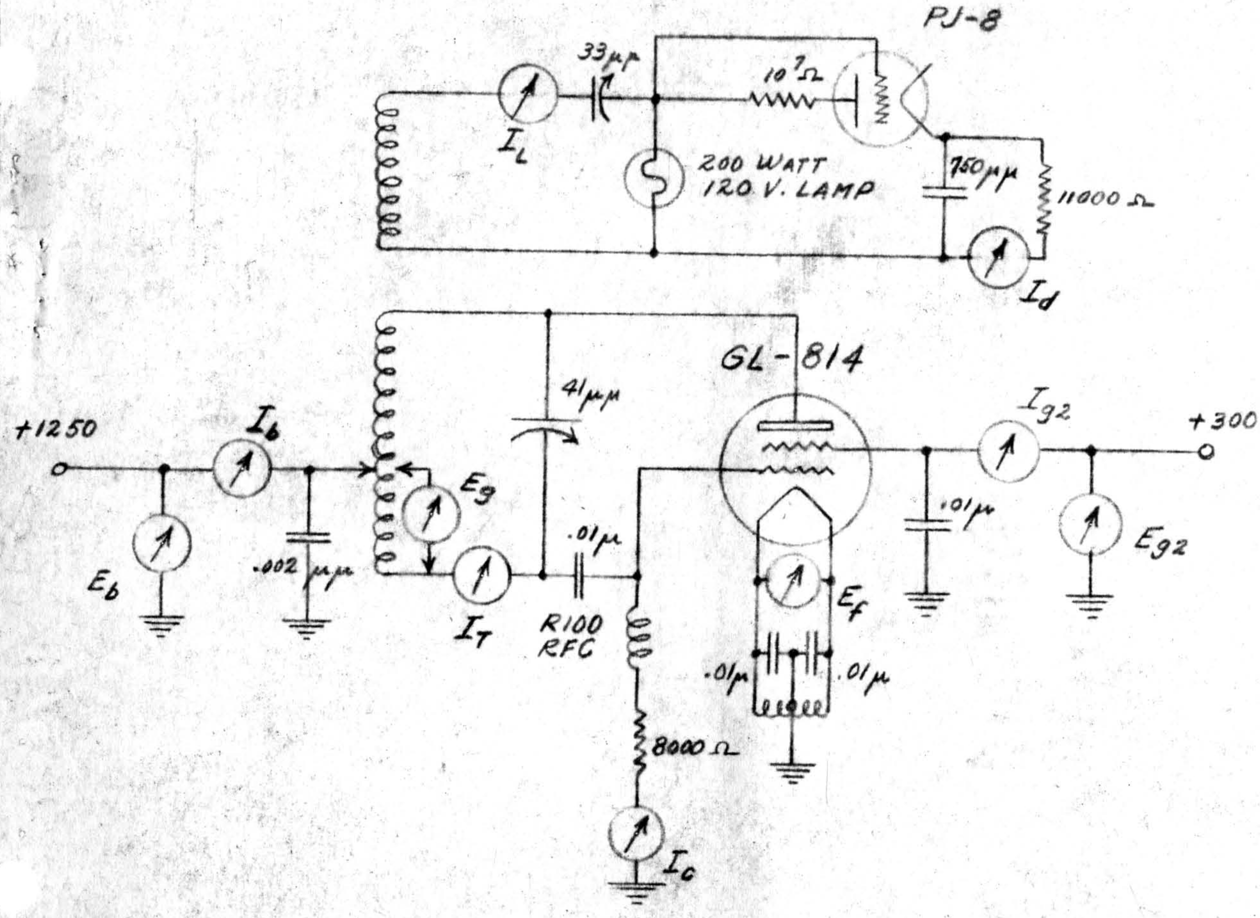
12-16-43




| COIL | TUBING | TURNS | DIAMETER | LENGTH |
|---|---|---|---|---|
| TANK | 1/4" O.D. COPPER | 9 | 3" O.D. | 5" |
| LOAD | 3/16" O.D. COPPER | 8 | 3" O.D. | 2 1/2" |

| READING | $I_T$ | $I_L$ | $E_f$ | $E_b$ | $I_b$ | $I_c$ | $I_d$ | $E_{g2}$ | $I_{g2}$ | $E_g$ |
|---|---|---|---|---|---|---|---|---|---|---|
| METER | 5 Amp. RF | 2.5 Amp. RF | 15 AV | 2000 DV | 300 Dma | 25 Dma | 10 Dma | 300 DV | 50 Dma | 150 RMS V.T.V. |

# 814 OSCILLATOR

## SHOWING PLACEMENT OF TEST METERS

| | | |
|---|---|---|
| REVISIONS | MADE BY C.W. Bleichner 12/2/43 | INSPECTED BY |
| | GENERAL ELECTRIC WORKS | K- SHEET NO. ____ CONT. ON SHEET ____ |
| PRINTS TO | | |