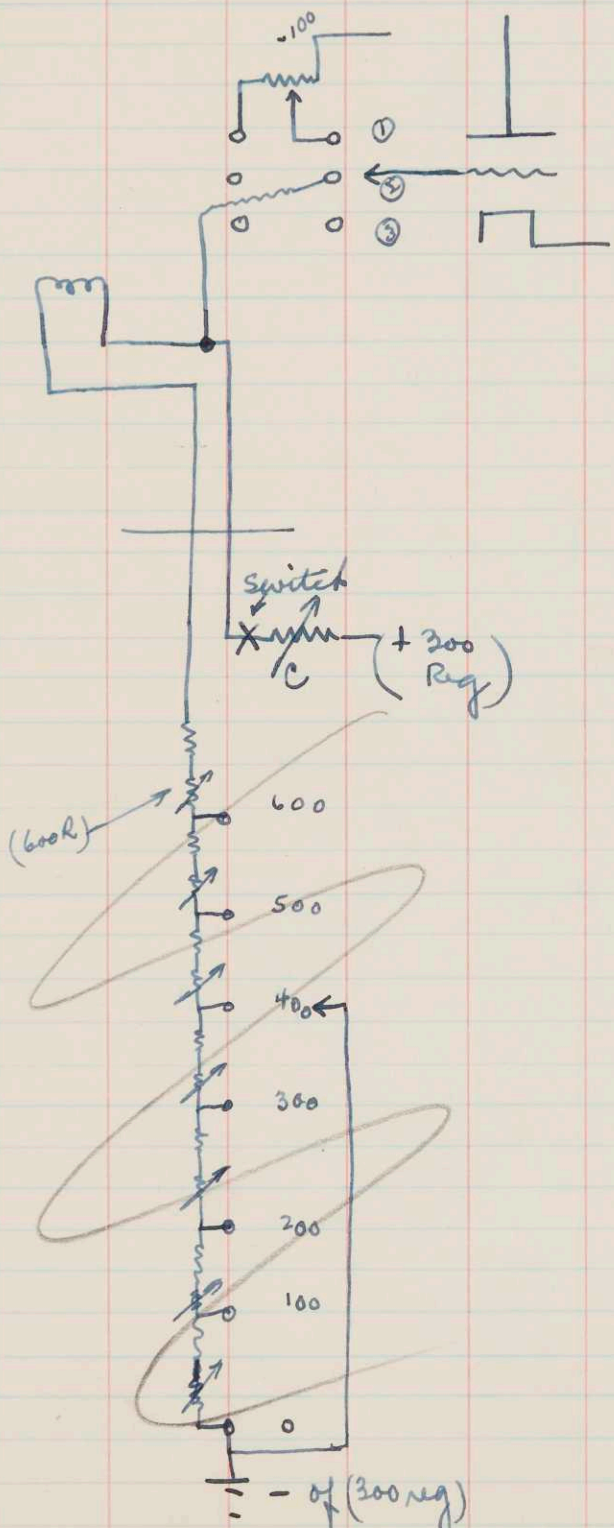
MC 241
Box 2 12

Design of an Electronic Galvanometer, 1942

3/28/42
①

Remarks on adjustment of internal lamp for checking 931



(a) Establish equality between external lamp and internal lamp at some selected point such as "60.0 This is ~~(b)~~ done with gain at "-100" by using external lamp first and adjusting mult gain until full scale on GE is obtained. Then close shutter and adjust control C and "600"R to give balance in position ② and full scale in position ①.

(b) Put gain up to full value and reduce lamp current by adjustment of C and "500R" so that balance is obtained in position 2 and full scale in position 1. (No change in mult. voltage).

(c) Back test: Gain at -100
Lamp at 600
" current to balance by means of "C" only.
Full scale should be obtained

Gain at 0
Lamp at 500
" current to balance
Full scale should be obtained.

(d) Set gain at -100
" Lamp at 500
Adjust C for balance
" Mult voltage to get full scale.

Set gain at 0
" Lamp at 400
Adjust "C" and "400R" for balance and full scale.

(e) Back test again

(f) Continue.

Electronic Galvanometer
Test of Variability of VR-105

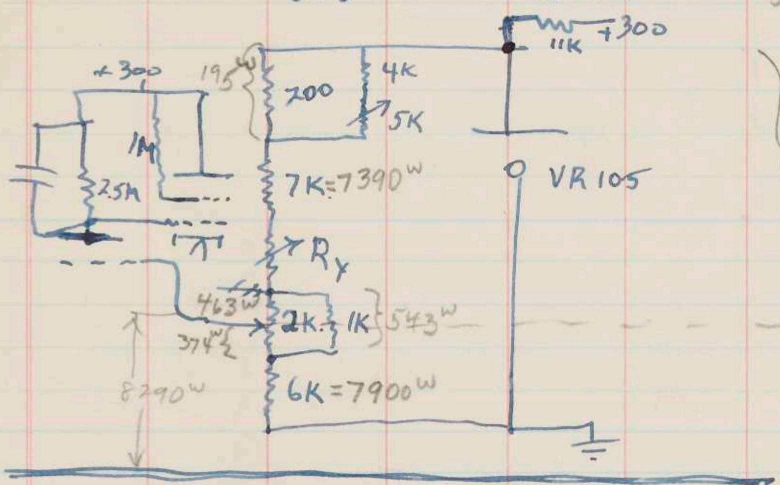
3-6-42
asw

Tube No.	R_x	Condition	E	R
1	~~500~~	~~steady~~		
	806	35 initial		7850
	637	5 min	51.3	
2	<0	initial		
	>0	2 min.		
	5w	5 min	53.3	
3	<0	initial		
	<0	2 min		
4	787	initial		
	608	6 min.	51.4	
5	637	12:18 initial		
	575	6 min.	51.5	
6	840	12:21 initial		
	578	4½ min.	51.5	

$$E = \frac{8143}{7886+8143+R_x} \times 105$$

$$= \frac{8140}{16030+R_x} \times 105$$

$$= \frac{855000}{16030+R_x}$$



$$\begin{array}{r} 195 \\ 7390 \\ 301 \\ \hline 7886 + R_x \end{array} \quad 301 = 543 \times \frac{463}{837}$$

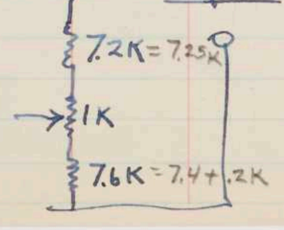
$$\begin{array}{r} 7886 \\ 8143 \\ \hline 16030 \end{array}$$

$$\begin{array}{r} 7900 \\ 243 \\ \hline 8143 \end{array} \quad 243 = 543 \times \frac{374}{837} =$$

7K → 6640w

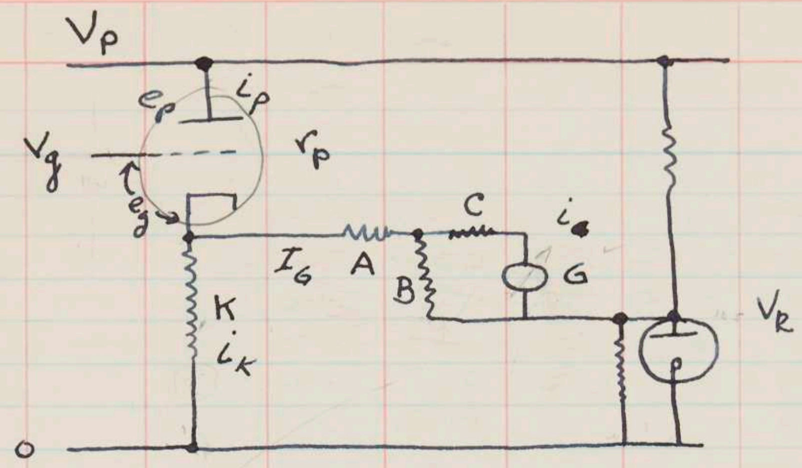
Tube No.	R_x	Condition	E	R
2	(−.750) 296 (−454)	1:46 initial	54.9	8380

Recommend: Total R = 16K



Cathode follower and Galvanometer

3/8/42



$$i_p = \frac{1}{r_p}(\mu e_g + e_p - \varepsilon)$$

$$e_g = V_g - i_K K$$

$$e_p = V_p - i_K K$$

$$i_p = i_K + I_G$$

$$I_G\left(A + \frac{B(C+G)}{B+C+G}\right) = V_R - i_K K$$

Solve for I_G as a function of V_g

$$r_p(i_K + I_G) = \mu(V_g - i_K K) + V_p - i_K K - \varepsilon$$

$$r_p I_G = \mu V_g - i_K(\mu K + K + r_p) + V_p - \varepsilon$$

$$I_G = \frac{\mu}{r_p} V_g - \frac{i_k}{r_p}\left(K(\mu+1) \cancel{B} - i_k + \frac{V_p - \varepsilon}{r_p}\right.$$

$$= \frac{\mu}{r_p} V_g - i_k K\left(\frac{\mu+1}{r_p}\right) - \frac{i_k K}{K} + \frac{V_p - \varepsilon}{r_p}$$

Eliminate $i_K K$

Let $A + \frac{B(C+G)}{B+C+G} = S$

$$V_R - I_G S = i_k K$$

$$\boxed{\text{For the network planned below } S = G \text{ for proper selection of } A\,B\,\&\,C.}$$

$$I_G = \frac{\mu}{r_p} V_g + I_G S\left(\frac{\mu+1}{r_p}\right) + \frac{I_G S}{K} - V_R\left(\frac{\mu+1}{r_p}\right) - \frac{V_R}{K} + \frac{V_p - \varepsilon}{r_p}$$

$$I_G\left(1 - \frac{S}{r_p}(\mu+1) - \frac{S}{K}\right) = \frac{\mu}{r_p} V_g - V_R \frac{(\mu+1)}{r_p} - \frac{V_R}{K} + \frac{V_p - \varepsilon}{r_p}$$

Condition for stand-by ~~cond~~ with no current through galvanometer.

$$\frac{\mu}{r_p} V_g = V_R \frac{(\mu+1)}{r_p} + \frac{V_R}{K} - \frac{V_p - \varepsilon}{r_p}$$

$$V_g = V_R + \frac{V_R}{\mu} + \frac{V_R\, r_p}{\mu\, K} - \frac{V_p - \varepsilon}{\mu}$$

$$= V_R \left[1 + \frac{1}{\mu}\left(1 + \frac{r_p}{K}\right)\right] - \frac{V_p - \varepsilon}{\mu}$$

To check take $\mu = 20$

$r_p = 10\,M$ $\quad K = 10\,K$

$V_p - \varepsilon = 280$

$V_R = 105$

$$V_g = 105\left[1 + \frac{1}{20}\left(1 + 1\right)\right] - \frac{280}{20}$$

$= 105 \times 1.1 - 14$

$$\begin{array}{r} 105 \\ 105 \\ \hline 1155 \end{array}$$

$= 101.5$ which is reasonable.

Define $\dot{I}_G = \dfrac{dI_g}{dV_g}$

$$\dot{I}_G\left(1-\frac{S}{r_p}(\mu+1)-\frac{S}{K}\right) = g_m$$

$$\dot{I}_G = \frac{g_m}{1-S\left(\frac{\mu+1}{r_p}+\frac{1}{K}\right)}$$

$$(I_G - i_g)B = (C+G)\, i_G$$

$$I_G B = i_G(B+C+G)$$

$$i_G = I_G \frac{B}{B+C+G}$$

$$\dot{i}_G = \dot{I}_G \frac{B}{B+C+G} = \frac{g_m}{\left(1+\frac{C}{B}+\frac{G}{B}\right)\left(1-S\left(\frac{\mu+1}{r_p}+\frac{1}{K}\right)\right)}$$

$$\frac{B}{B+C+G} = \frac{S-A}{C+G}$$

$$\dot{i}_G = \frac{g_m(S-A)}{(C+G)\left(1-S\left(\frac{\mu+1}{r_p}+\frac{1}{K}\right)\right)}$$

$$\frac{\left(\frac{1}{\left(\frac{1}{r_p}+\frac{1}{k}\right)}+A\right)(B+C)}{\frac{1}{\frac{1}{r_p}+\frac{1}{k}}+A+B+C} = D$$

Max sens is obtained with

$A = 0 \quad B = \infty \quad C = 0$

For this $S = G$

$$\dot{i}_{G\,max} = \frac{g_m G}{G\left(1 - G\left[\frac{\mu+1}{r_p}+\frac{1}{k}\right]\right)}$$

$$= \frac{g_m}{\left(1 - G\left(\frac{\mu+1}{r_p}+\frac{1}{k}\right)\right)}$$

define

$$\frac{\dot{i}_{G\,max}}{\dot{i}_G} = n \quad \text{(sens ratio)}$$

$$n = \frac{(C+G)\left[1 - S\left(\frac{\mu+1}{r_p} + \frac{1}{K}\right)\right]}{(S-A)\left[1 - G\left(\frac{\mu+1}{r_p} + \frac{1}{K}\right)\right]}$$

For max sens. and critical damping.

$$\frac{1}{D} = \frac{1}{r_p} + \frac{1}{K} = \frac{1}{\text{critical damping}}$$

$$\cancel{g_m}\ \cancel{\tfrac{1}{g_m}}\ \frac{\mu}{r_p} + \frac{1}{r_p} + \frac{1}{K} = \frac{1}{D} + g_m$$

For crit. damping at ~~max~~ $n=1$ only.

$$n = \frac{(C+G)\left[1 - g_m S - \frac{S}{D}\right]}{(S-A)\left[1 - g_m G - \frac{G}{D}\right]}$$

Also condition for constant damping.

$$\frac{(D+A)(B+C)}{A+B+C+D} = D$$

$$\frac{1}{D} = \frac{1}{D+A} + \frac{1}{B+C}$$

values of A, B, and C may be taken consistent with ~~abov~~ eq. and then from S which is known "n" may be calculated.

To make solution unique we could write

$$\frac{1}{G} = \frac{1}{A+B} + \frac{1}{C+G} \qquad (\alpha)$$

$$\frac{1}{D} = \frac{1}{B+C} + \frac{1}{A+D} \qquad (\beta)$$

$$n = \frac{(C+G)\left[\frac{1}{S} - g_m - \frac{1}{D}\right] S}{(S-A)\left[\frac{1}{G} - g_m - \frac{1}{D}\right] G}$$

Remember $S = G$

$$\frac{1}{S-A} = \frac{1}{B} + \frac{1}{C+G}$$

$$\frac{C+G}{S-A} = \left[1 + \frac{C+G}{B}\right]$$

$$\cancel{n = \frac{C+G}{B\left[\frac{1}{G} - g_m - \frac{1}{D}\right] G}}$$

$$n = \left[1 + \frac{C+G}{B}\right]\left[\frac{\left(1 - AM - \frac{MB(C+G)}{B+C+G}\right)}{\left(\frac{1}{G} - g_m - \frac{1}{D}\right) G}\right] \qquad (\gamma)$$

where $M = g_m + \frac{1}{D}$

Equations α, β, γ serve to determine definite values of A B & C for varies n values for a given G and D and gm.

By eliminating B two equations would be obtained which would give; first relation between A and ~~B~~C and; second n as a function of A and C. and therefor of A or C.

$$\frac{1}{A+B} = -\frac{1}{C+G} + \frac{1}{G}$$

$$A+B = \frac{(C+G)G}{+C}$$

$$B = \frac{G}{C}(C+G) - A = G + \frac{G^2}{C} - A$$

$$\frac{1}{B+C} = \frac{1}{D} - \frac{1}{A+D}$$

$$B+C = \frac{D(A+D)}{A} = D + \frac{D^2}{A}$$

$$B = D + \frac{D^2}{A} - C = G + \frac{G^2}{C} - A$$

$$DC + \frac{D^2C}{A} - C^2 = GC + G^2 - AC$$

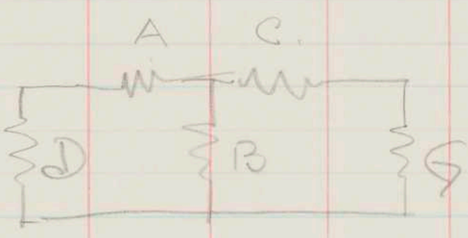
$$C^2 + C\left(G - A \mp D \mp \frac{D^2}{A}\right) + G^2 = 0$$

$$C + \frac{G^2}{C} = A + D + \frac{D^2}{A} - G$$

$$\frac{1}{G} = \frac{1}{G} + \frac{1}{D+G}$$

$\cancel{D} + \frac{G^2}{D} = G + \cancel{D} + \frac{D^2}{G} - \cancel{G}$

$G^3 = D^3$



$$\frac{(C+G)B}{B+C+G} + A = G \quad ✓$$

$$\frac{(A+D)B}{B+A+D} + C = D \quad ✓$$

$$(C+G)B + (C+G)A + AB = GB + GC + G^2$$

$$\left.\begin{aligned}(C+G)(A+B) + AB &= G(B+C+G)\\ (A+D)(C+B) + CB &= D(B+A+D)\end{aligned}\right\} \quad ✓$$

$C + G + A = G$

$C = -A$

This shows that for large values of B except $B = \infty$ - values of A or C will be called for.

Critical value

$D > G$ $\therefore$

with $A = 0$

$$\begin{cases} (C+G)B = G(B+C+G) \\ D(C+B) + CB = D(B+D) \end{cases}$$

$$C(B-G) = G(B+G) - BG$$

$$C = \frac{G^2}{B-G}$$

$$\frac{1}{C} = \frac{B}{G^2} - \frac{G}{G^2}$$

$$\frac{1}{C} + \frac{1}{G} = \frac{B}{G^2} \rightsquigarrow$$

$$\cancel{\frac{DG^2}{B-G} +}$$

$$C(D+B) = \overset{D^2}{D\cancel{(B+D)}} - \cancel{DB}$$

$$C = \frac{D}{} - \frac{DB}{D+B} = \frac{D^2}{B+D}$$

$$\frac{1}{C} + \frac{1}{G} - \frac{B}{G^2} = 0$$

$$\frac{G^2}{B-G} = \frac{D^2}{B+D}$$

$$\frac{B-G}{G^2} = \frac{B+D}{D^2}$$

$$B\left(\frac{1}{G^2} - \frac{1}{D^2}\right) = \frac{1}{G} + \frac{1}{D}$$

$$B = \frac{\cancel{\left(\frac{1}{G} + \frac{1}{D}\right)}}{\left(\frac{1}{G} - \frac{1}{D}\right)\cancel{\left(\frac{1}{G} + \frac{1}{D}\right)}} =$$

$$\boxed{\frac{1}{B} = \frac{1}{G} - \frac{1}{D}} \quad \text{For critical value of } B$$

$$\frac{1}{B} = \frac{1}{2} - \frac{1}{5}$$

$$\boxed{B_{crit} = \frac{DG}{D-G}} = \frac{10}{3} \times 10^3 = 3{,}333$$

This value and smaller are possible.

~~Consider case of B=100~~

Solve general eqn for C.

$$C(A+B-G) = G(\cancel{B}+G-A-\cancel{B}) - AB \quad ✓$$

$$= G^2 - A(G+B) \quad ✓$$

$$C = \frac{G^2 - A(G+B)}{A+B-G} \quad ✓$$

$$C(A+B+D) = \cancel{B(A+} D(A+\cancel{B}+D-\cancel{B}) - AB \quad ✓$$

$$C = \frac{D^2 + A(D-B)}{A+B+D} \quad ✓$$

$$\frac{G^2 - A(G+B)}{A+B-G} = \frac{D^2 + A(D-B)}{A+B+D} \quad ✓$$

$$\cancel{G^2A} + G^2B + G^2D - A^2G - ABG - \cancel{ADG} - \cancel{A^2B} - \cancel{AB^2} - ABD \quad ✓$$

$$-\cancel{G^2A} - D^2B + GD^2 - A^2D - ABG + \cancel{ADG} + \cancel{A^2B} + \cancel{AB^2} - ABD \quad ✓$$

$$-D^2A \quad -D^2B \quad +GD^2 \quad -A^2D \quad -ABG \quad +ADG \quad +A^2B \quad +AB^2 \quad -ABD \quad \cancel{-GD^2}$$

$$A(G^2-D^2) + (G^2-D^2)B + GD(G+D) - A^2(G+D) - 2AB(G+D) = 0 \quad ✓$$

$$\cancel{(G-D)(BG+BD+GD) = (G+D)(A^2+2AB+B^2)}$$

$$+\cancel{GB^2+DB^2}$$

✓

$$(A+B)(G-D)\cancel{(G+D)} + GD\cancel{(G+D)} - A^2\cancel{(G+D)} - 2AB\cancel{(G+D)} = 0$$

$$(A+B)(G-D) - (A^2+2AB) + GD = 0 \quad ✓$$

Test for case of $D > G$ and $A = 0$

$$B(G-D) + GD = 0$$

$$B = \frac{GD}{D-G} = \left(\frac{1}{G} - \frac{1}{D}\right)^{-1}$$

$$\frac{1}{B_{crit}} = \frac{1}{G} - \frac{1}{D}$$

This checks page 11

✓

$$A^2 + A(2B - G + D) = GD + BG - BD$$

$$A^2 + 2A\left(B + \frac{D-G}{2}\right) + \left(\cancel{2}B + \frac{D-G}{2}\right)^2 =$$

$$\frac{1}{4}\left[4B^2 + D^2 + G^2 + 4BD - 4BG - 2DG\right]$$

$$-BD + BG + GD$$

$$\left[B^2 + \frac{D^2}{4} + \frac{G^2}{4} + \frac{GD}{2}\right] \quad ✓$$

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$$A + B + \frac{D-G}{2} = \pm\sqrt{B^2 + \tfrac{1}{4}(D+G)^2}$$

$$A = -B - \frac{D-G}{2} + \sqrt{}$$

$$A = B\left[\left(1 + \frac{(D+G)^2}{4B}\right)^{1/2} - 1 - \frac{D-G}{2B}\right]$$

$$A = B\left[\left(1 + \left(\frac{D+G}{2B}\right)^2\right)^{1/2} - \left(1 + \frac{D-G}{2B}\right)\right]$$

Test for $A = 0$

$$1 + \left(\frac{D+G}{2B}\right)^2 = \left[1 + \frac{D-G}{2B}\right]^2$$

$$\cancel{1} + \frac{\cancel{D^2}}{\cancel{4}B^2} + \frac{\cancel{2}DG}{\cancel{4}B^{\cancel{2}}}_{2} + \frac{\cancel{G^2}}{4B^2} = \cancel{1} + \frac{\cancel{2}D}{\cancel{2}\cancel{B}} - \frac{\cancel{2}G}{\cancel{2}\cancel{B}} + \frac{\cancel{D^2}}{4B^2} + \frac{\cancel{G^2}}{4B^2} - \frac{2DG}{4B^2}$$

$$\frac{DG}{B} = D - G$$

$$B = \frac{DG}{D-G}$$

OK

~~which is wrong by factor 2~~

Berit $B = \frac{5 + 2000}{3} = 3333$

c

5/8/42

$$A = -B - \frac{D-G}{2} + \left(B^2 + \frac{1}{4}(D+G)^2\right)^{1/2}$$

$$A = G\left[-\frac{2B+D-G}{2G} + \left[\frac{4B^2+(D+G)^2}{4G^2}\right]^{1/2}\right]$$

$$= G\left[\frac{D+G}{2G}\left\{1+\frac{4B^2}{(D+G)^2}\right\}^{1/2} - \frac{D-G}{2G}\left\{1+\frac{2B}{D-G}\right\}\right]$$

$$= \frac{G}{2}\left[\left\{1+\frac{D}{G}\right\}\left\{1+\frac{4B^2}{(D+G)^2}\right\} - \left\{\frac{D}{G}-1\right\}\left\{1+\frac{2B}{D-G}\right\}\right]$$

See also p 19

Try $B = 1500$

$\frac{D}{G} = \frac{5}{2}$ $\quad 1+\frac{D}{G} = \frac{7}{2}$ $\quad \frac{D}{G} - 1 = \frac{3}{2}$

$$= 1000\left[\frac{7}{2}\left\{ \qquad \right\} - \frac{3}{2}\left\{1 + \frac{3000}{3000}\right\}\right]$$

$$1 + \frac{\overset{9}{2.25 \times 4}}{49}$$

$.1837$

$(1.1837)^{1/2}$

$1.088 \times \frac{7}{2} = 3.81$

Looks as though this should be +

$$\begin{array}{r} 3.81 \\ 3.00 \\ \hline .81 \end{array}$$

$A =$ ~~3,810~~ 810

$$R = \frac{5830}{1190} = 4.9$$

for all values of ∇ B smaller than the critical one A is real and positive.

~~$C = D^2$~~ Consider critical value and compute n of page 7.

$$C_{crit} = \frac{D^2}{B+D} =$$

$$\frac{1}{C'} = \frac{B'}{D^2} + \frac{1}{D} \qquad \frac{1}{B'} = \frac{1}{G} - \frac{1}{D}$$

$$B' = \frac{1}{\left(\frac{1}{G} - \frac{1}{D}\right)}$$

$$\frac{1}{C'} = \frac{1}{D^2\left(\frac{1}{G} - \frac{1}{D}\right)} + \frac{1}{D}$$

$$= \frac{1}{D^2\left(\frac{1}{G} - \frac{1}{D}\right)} + \frac{1}{D} = \frac{1}{\frac{D^2}{G} - D} + \frac{1}{D}$$

$$= \frac{\cancel{D} + \frac{D^2}{G} - \cancel{D}}{\cancel{D}\left(\frac{D^2}{G} - D\right)} = \frac{\frac{D^2}{G}}{\frac{D^2}{G} - D^2}$$

$$C' = \frac{\frac{D^2}{G}}{\frac{D}{G}} - \frac{D}{\frac{D}{G}} = D - G$$

$C' = 3000$

Critical value of C is

$$C' = D - G$$

$$B' = \frac{GD}{D-G}$$

$\Big[$ Crit S

Crit n. $\quad n' = \dfrac{C' + G}{C - O} = \dfrac{3000 + 2000}{2000} = 2.5$

Mistake in there

$$n' = \left[1 + \frac{D - \cancel{G} + \cancel{G}}{\frac{GD}{D-G}}\right]\left[\frac{1 - 0 - \dfrac{\left(g_m + \frac{1}{D}\right)\left(\frac{GD}{D-G}\right) D}{\frac{GD}{D-G} + D \frac{D-G}{D-G}}}{\left(\frac{1}{G} - g_m - \frac{1}{D}\right) G}\right]$$

$$n' = \left[1 + \frac{D-G}{D}\right]\left[\frac{1 - \left(g_m + \frac{1}{D}\right) G}{\left(\frac{1}{G} - g_m - \frac{1}{D}\right) G}\right]$$

$$n' = \left[2 - \frac{G}{D}\right]\left[\frac{\left(1 - g_m G + \frac{G}{D}\right)}{\left(1 - g_m G - \frac{G}{D}\right)}\right]$$

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Something wrong here

$$n' = \left[2 - \frac{G}{D}\right] \frac{1 - G\left(g_m - \frac{1}{D}\right)}{1 - G\left(g_m + \frac{1}{D}\right)}$$

Take $D = 5000$

$G = 2000$

$\frac{G}{D} = \frac{2}{5}$ $\quad \frac{1}{D} = .2 \times 10^{-3}$

$g_m = 5.5 \times 10^{-3}$

$g_m G = 11$

$$n' = \overset{(1.6)}{\left[2 - \frac{2}{5}\right]} \left[\frac{1 - 11 + .4}{1 - 11 - .4}\right.$$

$$1.6 \times \frac{10.4}{9.6} = \cancel{1.735} \quad 2.5$$

Values of n' between 1 and ~~5~~ 2.5

cannot be obtained

under conditions specified

as $G = 2000$

$D = 5000$

$g_m = 5.5 \times 10^{-3}$ (6SN7 tubes parallel)

$$3333\left[+\left\{1+\left(\frac{7000}{6667}\right)^2\right\}^{1/2}-\left\{1+\frac{3000}{6667}\right\}\right]=4$$

$2.07^{1/2}$

$1.435 - 1.50$

Should be zero

$$A = B\left[\left\{1+\left(\frac{D+G}{2B}\right)^2\right\}^{1/2} - \left\{1+\frac{D-G}{2B}\right\}\right]$$ See 19

For small values of B.

$$A = B\left[\frac{B}{D+G} + \cancel{1+}\ \frac{D+G}{2B} - 1 - \frac{D-G}{2B}\right] = B\left[\frac{G}{B} - 1 + \frac{B}{D+G}\right]$$

$$\doteq G - B + \frac{B^2}{D+G} = G\left[1 - \frac{B}{G} + \frac{B^2}{(D+G)G}\right]$$

$$\doteq G\left[1 - \frac{BD + BG - B^2}{(D+G)G}\right]$$

$$\doteq G\left[1 - \frac{B}{G}\cdot\frac{(D+G-B)}{(D+G)}\right]$$

$$\doteq G\left[1 - \frac{B}{G}\left(1 - \frac{B}{D+G}\right)\right] \longrightarrow$$

Put exact expression in this form.

$$A = \left[\frac{\cancel{B}(D+G)}{2\cancel{B}}\left\{1+\frac{(2B)^2}{(D+G)^2}\right\}^{1/2} - \frac{\cancel{B}(D-G)}{2\cancel{B}}\left\{1+\frac{2B}{D-G}\right\}\right]$$

~~$A = \left[\frac{D+G}{2} \right.$~~

Best form

$$\boxed{A = G\left[\frac{1}{2}\left\{1+\frac{D}{G}\right\}\left\{1+\frac{2B^2}{(D+G)^2}\right\}^{1/2} + \frac{1}{2}\left\{1-\frac{D}{G}\right\}\left\{1+\frac{2B}{D-G}\right\}\right] \quad -\frac{1}{2}\left\{\frac{D}{G}-1\right\}}$$

Check approx.

$$A \doteq G\left[\frac{1}{2}\left\{1+\frac{D}{G}\right\}\left\{1+\frac{2B^2}{(D+G)^2}\right\} + \frac{1}{2}\left\{1-\frac{D}{G}\right\}\left\{1+\frac{2B}{D-G}\right\}\right]$$

$$\frac{G}{2}\left[\cancel{1} + \cancel{\frac{D}{G}} + \frac{2B^2}{(D+G)^2} + \frac{2DB^2}{G(D+G)^2} \cancel{-1} + \frac{D}{G}\frac{2B}{D-G} - \cancel{\frac{D}{G}} + \frac{2B}{D-G}\right]$$

$$\left[\cancel{\frac{2D}{G} - \frac{2B}{D-G}} + \quad 2 + \frac{2B^2(G+D)}{(D+G)^2 G} - \frac{2B(D-G)}{G(D-G)}\right.$$

$$\cancel{\left[\frac{2D}{G} + \frac{2B^2(G+D)}{G(D+G)^2} + \frac{2B(D-G)}{G(D-G)}\right.}$$

$$\cancel{A \doteq G\left[\frac{D+B}{G} + \frac{2B^2}{G(D+G)}\right]}$$

$$A \doteq G\left[1 - \frac{B}{G}\left[1 - \frac{B}{D+G}\right]\right]$$ which checks (18)

$$C = D\left[\frac{1}{2}\left\{1+\frac{G}{D}\right\}\left\{1+\frac{4B^2}{(D+G)^2}\right\}^{1/2} + \frac{1}{2}\left\{1-\frac{G}{D}\right\}\left\{1+\frac{2B}{G-D}\right\}\right]$$

$$\doteq D\left[\frac{1}{2}\left\{1+\frac{2B^2}{(D+G)^{\cancel{2}}}\,\frac{\cancel{(D+G)}}{D}\right\} + \frac{1}{2}\left\{1+\frac{2B}{\cancel{(G-D)}}\,\frac{D-G}{D}\right\}\right]$$

$$= D\left[1+\frac{\cancel{2}B^2}{D(D+G)} - \frac{\cancel{2}B}{D}\right]$$

$$= D\left[1 - \frac{B}{D}\left[1-\frac{B}{D+G}\right]\right]$$

Write Exact eqn.

$$C = D\left[\frac{1}{2}\left\{1+\frac{G}{D}\right\}\left\{1+\frac{4B^2}{(D+G)^2}\right\}^{1/2} - \frac{1}{2}\left\{\frac{G}{D}-1\right\}\left\{1-\frac{2B}{D-G}\right\}\right]$$

For any value of B the corresponding value of A or C may be computed.

21

3/8/42

By making S = G Eqn on 6 becomes

$$n = \frac{(C+G)\left[1 - \cancel{G}\left(\frac{\mu+1}{r_p} + \frac{1}{k}\right)\right]}{(G-A)\left[\qquad\right]}$$

$$n = \frac{C+G}{G-A} = \frac{1+\frac{C}{G}}{1-\frac{A}{G}}$$

$\cancel{n =}$

$$\frac{C}{G} = \frac{D}{G}\left[1 - \frac{B}{D}\left[1 - \frac{B}{D+G}\right]\right]$$

Let $\cancel{B} = B\left[1 - \frac{B}{D+G}\right]$

$$\frac{C}{G} = \frac{D}{G}\left[1 - \frac{B}{D}\right]$$

$$\frac{A}{G} = \left[1 - \frac{B}{G}\right]$$

$$n = \frac{1 + \frac{D}{G}\left[1 - \frac{B}{D}\right]}{1 - 1 + \frac{B}{G}} = \cancel{\frac{G}{B} + \frac{D}{B}}$$

$$n = \frac{1 + \frac{D}{G}\left[1 - \frac{\beta}{D}\right]}{\frac{\beta}{G}} = \frac{G}{\beta} + \frac{D}{\beta} - 1$$

$$n \doteq \frac{G+D}{B\left[1 - \frac{B}{D+G}\right]}$$

$$\doteq \frac{(D+G)^2}{B\left[G+D-B\right]}$$

$$\frac{(D+G)^2}{n} = B\left[G+D-B\right]$$

$$B^2 - 2B\left(\frac{G+D}{2}\right) + \frac{(G+D)^2}{4} = -\frac{(D+G)^2}{n} + \frac{(G+D)^2}{4}$$

$$B - \frac{G+D}{2} = \pm\left\{\frac{(G+D)^2}{4} - \frac{(D+G)^2}{n}\right\}^{1/2}$$

$$B = \frac{G+D}{2} \pm \left\{\frac{(G+D)^2}{4} - \frac{(D+G)^2}{n}\right\}^{1/2}$$

$$= \frac{G+D}{2}\left[1 - \left\{1 - \frac{4}{n\cancel{(G+D)}}\right\}^{1/2}\right]$$

3/8/42

$$B = \frac{G+D}{2}\left[1 - 1 + \frac{2}{n\cancel{(G+D)}}\right]$$

$$B \doteq \frac{G+D}{\cancel{2}} \times \frac{\cancel{2}}{n\cancel{(G+D)}} =$$

$$B \doteq \frac{G+D}{n}$$

$$C \doteq D\left[1 - \frac{G+D}{nD}\left[1 - \frac{\cancel{G+D}}{n\cancel{(D+G)}}\right]\right]$$

$$\cancel{= D\left[1 - \frac{G+D}{n} + \frac{B}{\cdot}\right.}$$

$$C \doteq D\left[1 - \frac{G+D}{nD}\left[1 - \frac{1}{n}\right]\right] = D\left[1 - \left(1 + \frac{G}{D}\right)\left(\frac{1}{n} - \frac{1}{n^2}\right)\right]$$

$$A \doteq G\left[1 - \frac{G+D}{nG}\left[1 - \frac{1}{n}\right]\right] = G\left[1 - \left(1 + \frac{D}{G}\right)\left(\frac{1}{n} - \frac{1}{n^2}\right)\right]$$

Numerical

$G = 2000$ $\qquad \frac{D}{G} = \frac{5}{2} = 2.5$

$D = 5000$

$n = 10$ $\qquad \frac{G}{D} = .4$

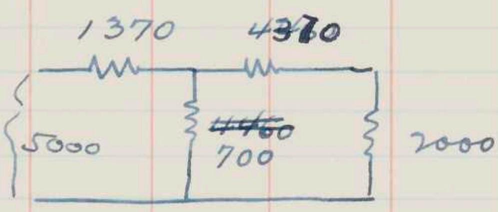
$B \doteq \frac{7000}{10} = 700$

$A \doteq 2000\left[1 - (3.5)(.09)\right]$ $\qquad$ 1.000 / .315 / .685

$A = 1370$

$C = 5000\left[1 - (1.4)(.09)\right]$ $\qquad$ .108 / ~~.892~~ $\qquad$ .126 / .874

$= 4370$



To check

703

$$\frac{6370 \times 700}{7070} + 1370 = 2000$$

1365

625

$$\begin{array}{r} 1370 \\ 630 \\ \hline 2000 \end{array}$$

$$\frac{6370 \times 700}{7070} + 4370 = 5000$$

$$\begin{array}{r} 4370 \\ 630 \\ \hline 5000 \end{array} =$$

$$n = \frac{1 + \frac{4370}{2000}}{1 - \frac{1370}{2000}} = \frac{1 + 2.185}{1 - .685} = \frac{3.185}{.315} = 10.1$$

6825

As a second approx
take $\underline{B = 703}$

$$\begin{array}{r} 703 \\ 703 \\ \hline 2109 \\ 49210 \\ \hline 4942 \end{array}$$

$$C = 5000\left[\frac{1}{2}\,1.4\left\{1+\frac{4\times494210}{49\times10^6}\right\}^{1/2} + \frac{1}{2}\times.6\left\{1-\frac{1403}{3000}\right\}\right]$$

$.468$

$1+.0403$

$.532$

$.7\times1.02$

$$\begin{array}{r} .1596 \\ .714 \\ \hline .8736 \end{array}$$

$\underline{C = 4368.0}$

$$A = 2000\left[\frac{1}{2}\cdot3.5\times1.02 - \frac{1}{2}(1.5)\left(\frac{\cancel{.532}}{\cancel{.468}}\right)\right]$$

1.468 ✓

$\cancel{1.496}\ \cancel{.398}$

4404
1101

$$\begin{array}{r} 1.785 \checkmark \\ 1.101 \\ \hline .684 \end{array}$$

$$\begin{array}{r} 35 \\ .51 \\ \hline 35 \\ 175 \\ \hline 1785 \end{array}$$

$\underline{A = 1368}$

684
316

$$n = \frac{1+\frac{4368}{2000}}{1-\frac{1368}{2000}} = \frac{3.184}{.316} = 10.07$$

Use $\left.\begin{array}{l} B = 705 \\ A = 1366 \\ C = 4366 \end{array}\right\}$ for $n = 10$

$n = 20$

$B = \frac{7000}{20} = 350$

$A = 2000\left[1 - (3.5)(.05 - .0025)\right]$

$.0475$

$.1663$

$.8337$

$= 16674$

$A = 1667$

$C = 5000\left[1 - 1.4 \times .0475\right]$

$.0665$

$.9335$

$C = 46685$

$C = 4668$

$n = \frac{6668}{333} = 20.02$

$n = 50 \qquad B = 140$

$A = 2000\left[1 - 3.5(.02 - .0004)\right)$

$.0196$

$.0200$
$.0004$
196

$.0685$

$\cancel{9629}$

9315

$= \cancel{19258}\ 18630$

$A = \cancel{1926}\ 1863$

$C = 5000\left[1 - 1.4 \times .0196\right]$

$.\cancel{996}$

$\cancel{.014}$

$.0274$

$.9726$

$= \cancel{4980.0}$

$= 48630$

$\cancel{4980}\ 4863$

3/18/42

$n = 100$

$B = 70$

$A = 2000 [1 - 3.5 \times .0099]$

.0346

.9654

$= 19708$

$\underline{A = 1971}$

$C = 5000 [1 - 1.4 \times .0099$

.0139

.9861

$C = 49305$

$\underline{C = 4930}$

---

5 & 2

$n = 5 \quad B \doteq 1400$

$A = 2000 [1 - 3.5 (.2 - 04)$

.16

.56

$\doteq 880$

$C = 5000 [1 - 1.4 \times .16$

.224

.776

$C \doteq 3870$

For $n = 5$ try $B = 1500$

$$A = 2000\left[\underbrace{\frac{1}{2}\cdot 3.5}_{1.75}\left[1 + \frac{4\times 2.25\times 10^6}{49\times 10^6}\right]^{1/2} - (.75)\left(1 + \frac{3000}{\cancel{7000}\;300}\right)\right]$$

$(1.204)^{1/2}$

1.096 1.077

~~1.108~~
~~1.077~~

1.918
1.072
.846

$\underline{A = 1692}$

This is much too large

$$C = 5000\left[\cancel{\tfrac{1}{2}\,1.4}\ .7\times 1.096 + .3\left(1 - \frac{3000}{3000}\right)\right]$$

.7672

$\underline{C = 3836.0}$

$$n = \frac{3836 + 2000}{2000 - 1692} = \frac{5836}{308} = 19$$

$$A \doteq 2000\left[1 - \left(1 + \frac{5}{2}\right)(.20 - .04)\right.$$

3.5 .16

.56
.44

$= 880$

$$n \doteq \frac{5830}{1120} = 5.2$$

Try $B = 2000$ in exact

$$A = 2000\left[\frac{1}{2}\left[3.5\right]\left[1+\frac{4\times4\times10^6}{49\times10^6}\right]^{1/2} - \tfrac{1}{2}1.5\times\left[1+\frac{4}{3}\right]\right]$$

1.327

1.151×1.75

$\cancel{2.333}$ .3

$\frac{7}{3} \times \cancel{1.8} = 2.1$

$- 1.05$

$$\begin{array}{r} 2.015 \\ 1.050 \\ \hline .965 \end{array}$$

$\frac{G}{D} = .4$

$$C = 5000\left[\frac{1}{2}\left[1.4\{1.151\} + \frac{1}{2}\,.6\times\left(1-\frac{4000}{3000}\right)\right]\right]$$

$.8057 \quad - .1$

$.7057$

$C = 3528.5$ for $B = 2000$

Form 18

$$A = \left[\frac{7000}{2}\{1.151\} - \frac{3000}{2}\left(-\frac{1}{3}\right)\right)$$

500

$$\begin{array}{r} 4040 \\ 500 \\ \hline 45 \end{array}$$

Expression for A seems to be wrong.

$$A = 2000\left[1.151 - 1 + \frac{3000}{4000}\right]$$

$1.151 \quad - 1.75$

$$\begin{array}{r} 1.15 \\ \hline .7 \end{array}$$

$A = -1400$

Try $B = 1460$ for $n = 5$

$$A = 2000\left[1.75\left[1+\frac{4\times .2135}{49}\right]^{1/2} - .75\left(1+\frac{2920}{3000}\right)\right.$$

$(1.174)^{1/2}$ 1.973

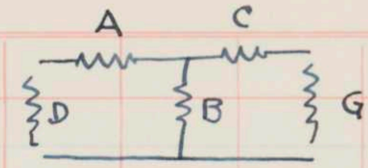
1.082

1897
1.480
.417

$A = 834$

$$n = \frac{5836}{1166} = 5.00$$

Final equations:



$$A = B\left[\left\{1+\left(\frac{D+G}{2B}\right)^2\right\}^{1/2} - \left\{1+\frac{D-G}{2B}\right\}\right]$$

or

$$A = \frac{nG-D}{n+1}$$ Best of all

$$A = \frac{G}{2}\left[\left\{1+\frac{D}{G}\right\}\left\{1+\frac{4B^2}{(D+G)^2}\right\}^{1/2} - \left\{\frac{D}{G}-1\right\}\left\{1+\frac{2B}{D-G}\right\}\right]$$

or

$$A \doteq G\left[1-\frac{B}{G}\left(1-\frac{B}{D+G}\right)\right]$$

Critical value of A is $A'=0$
By setting $A=0$ in 1st eqn

Critical value of $B' = \frac{DG}{D-G} = \frac{G}{1-\frac{G}{D}}$

$A = 0$ when $n' = \frac{D}{G}$ critical value.

Final eqn for C.

$$C = B\left[\left\{1+\left(\frac{D+G}{2B}\right)^2\right\}^{1/2} - \left\{1 - \frac{D-G}{2B}\right\}\right]$$

or $$C = \frac{nD-G}{n+1}$$ Best of all

$$C = \frac{D}{2}\left[\left\{1+\frac{G}{D}\right\}\left\{1+\frac{4B^2}{(D+G)^2}\right\}^{1/2} + \left\{1-\frac{G}{D}\right\}\left\{1-\frac{2B}{D-G}\right\}\right]$$

or

$$C \doteq D\left[1 - \frac{B}{D}\left(1 - \frac{B}{D+G}\right)\right]$$

Critical value of C is

$$C' = D-G$$

Let $X^2 = 1 + \left(\frac{D+G}{2B}\right)^2$

$$C = BX - B + \frac{D-G}{2}$$

$$A = BX - B - \frac{D-G}{2}$$

$$C - A = D - G$$

$$C = (D-G) + A \qquad G - A = D - C$$

$$C + G = D + A$$

$$n = \frac{D+A}{D-C} = \frac{G+C}{G-A} = \frac{G+C}{D-C}$$

$$(D-C)n = G + C \qquad (G-A)n = G + C$$

$$nD - G = C(n+1)$$

$$C = \frac{nD-G}{n+1}$$

$$A = \frac{nG-D}{n+1}$$

From start

$$B = \frac{(G+C)(G-A)}{A+C}$$

$$A+C = \frac{(n-1)(G+D)}{n+1}$$ From 32

$$(G+C) = n(D-C) = n(G-A)$$

$$(G-A) = (D-C)$$

$$B = \frac{n\,(G-A)^2}{\frac{(n-1)}{n+1}(G+D)} = \frac{\frac{n}{(n+1)^2}\left(\cancel{Gn} + G - \cancel{nG} + D\right)^2}{\frac{n-1}{(n+1)}\ G+D}$$

$$= \frac{n\,(G+D)}{n^2-1} = \frac{G+D}{n-\frac{1}{n}}$$

$$A = \frac{nG-D}{n+1} = G\,\frac{n-\frac{D}{G}}{n+1}$$

$$C = \frac{nD-G}{n+1} = D\,\frac{n-\frac{G}{D}}{n+1} = G\,\frac{\frac{D}{G}n-1}{n+1}$$

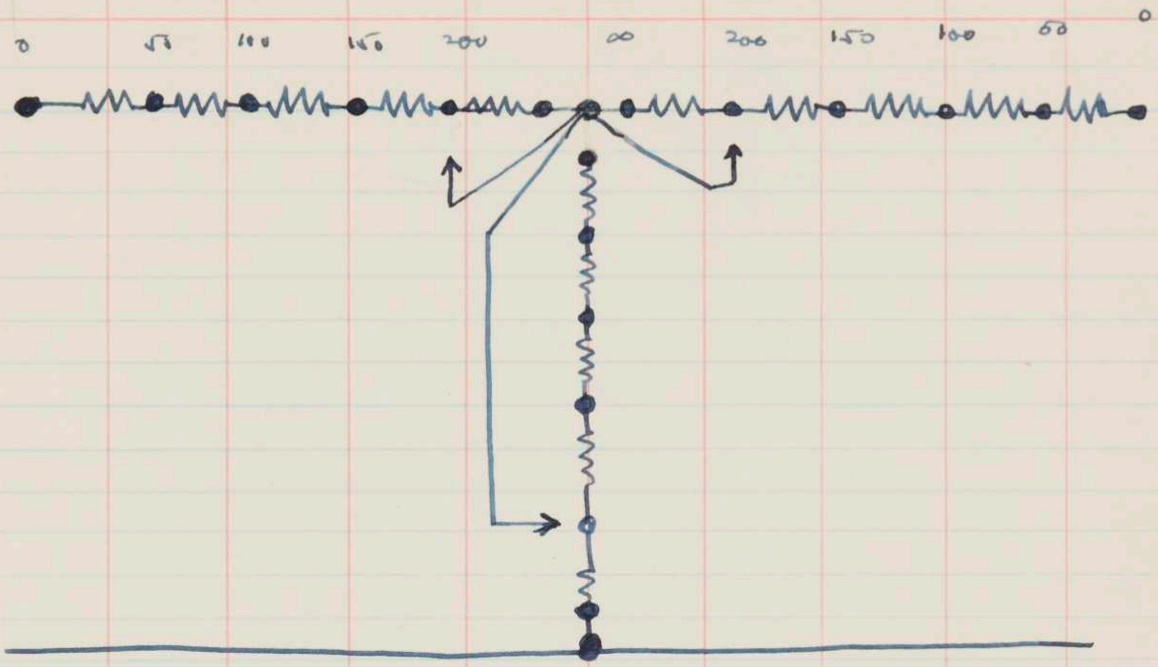
$$B = G\,\frac{1+\frac{D}{G}}{n-\frac{1}{n}} = G\,\frac{n\left(1+\frac{D}{G}\right)}{n^2-1}$$

$G = 2000$
$D = 5000$

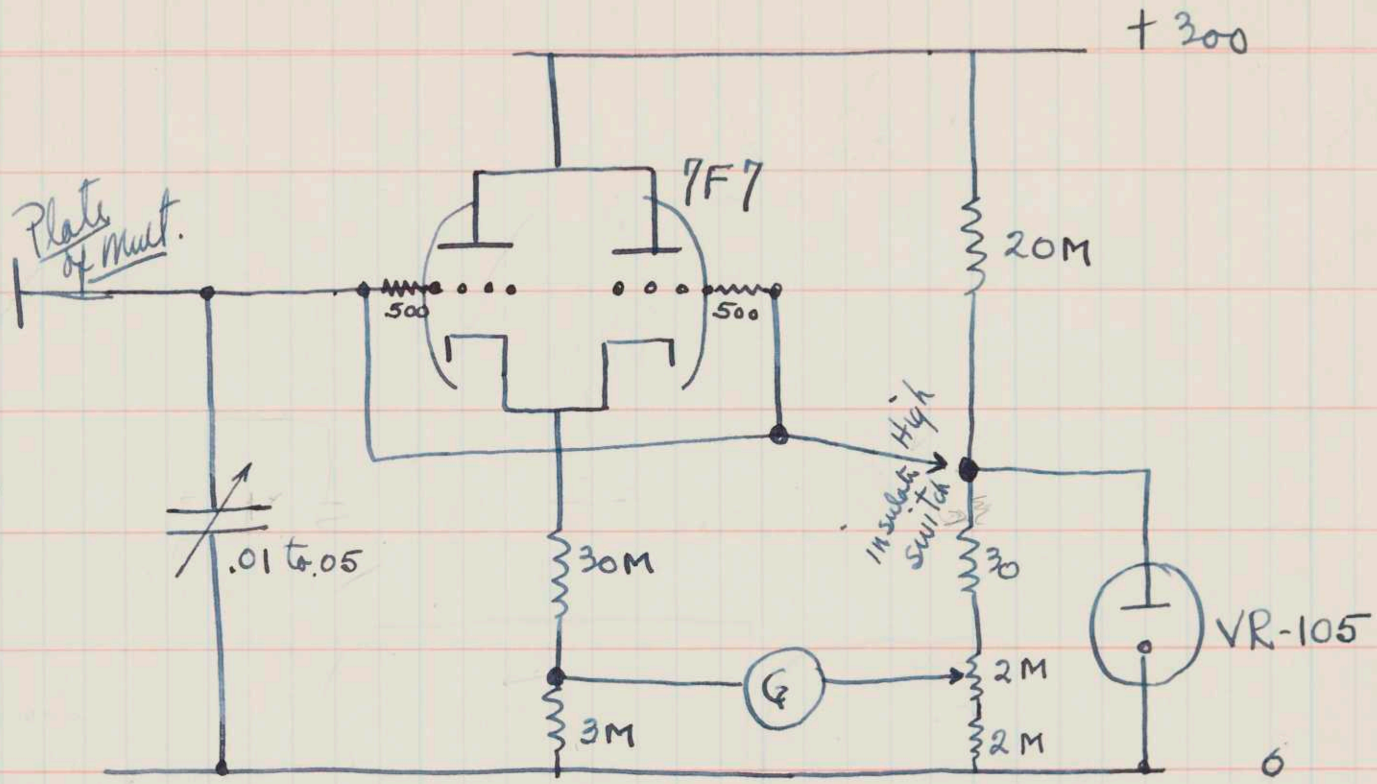
$\frac{D}{G} = 2.5$

n^2	n		A	B	C	3.5 n	$n - 2.5$	$\frac{n-2.5}{n+1}$
1	1		0	∞	0			
10	$\sqrt{10}$	3.1623	318.5	2460	796 ~~955~~.0	11.06	.6623	.1592
100	10		1364	707	3410.	35	7.5	
1000	$\sqrt{1000}$	31.623	1785	221.3	4464.	110.6	29.123	.893
10,000	100		1931	70.0	4878	350	97.5	.9655

n D



$\sqrt{10}$



Circuit for measuring "flash" using GE Recorder. (File in the "System")

W. B. Nottingham

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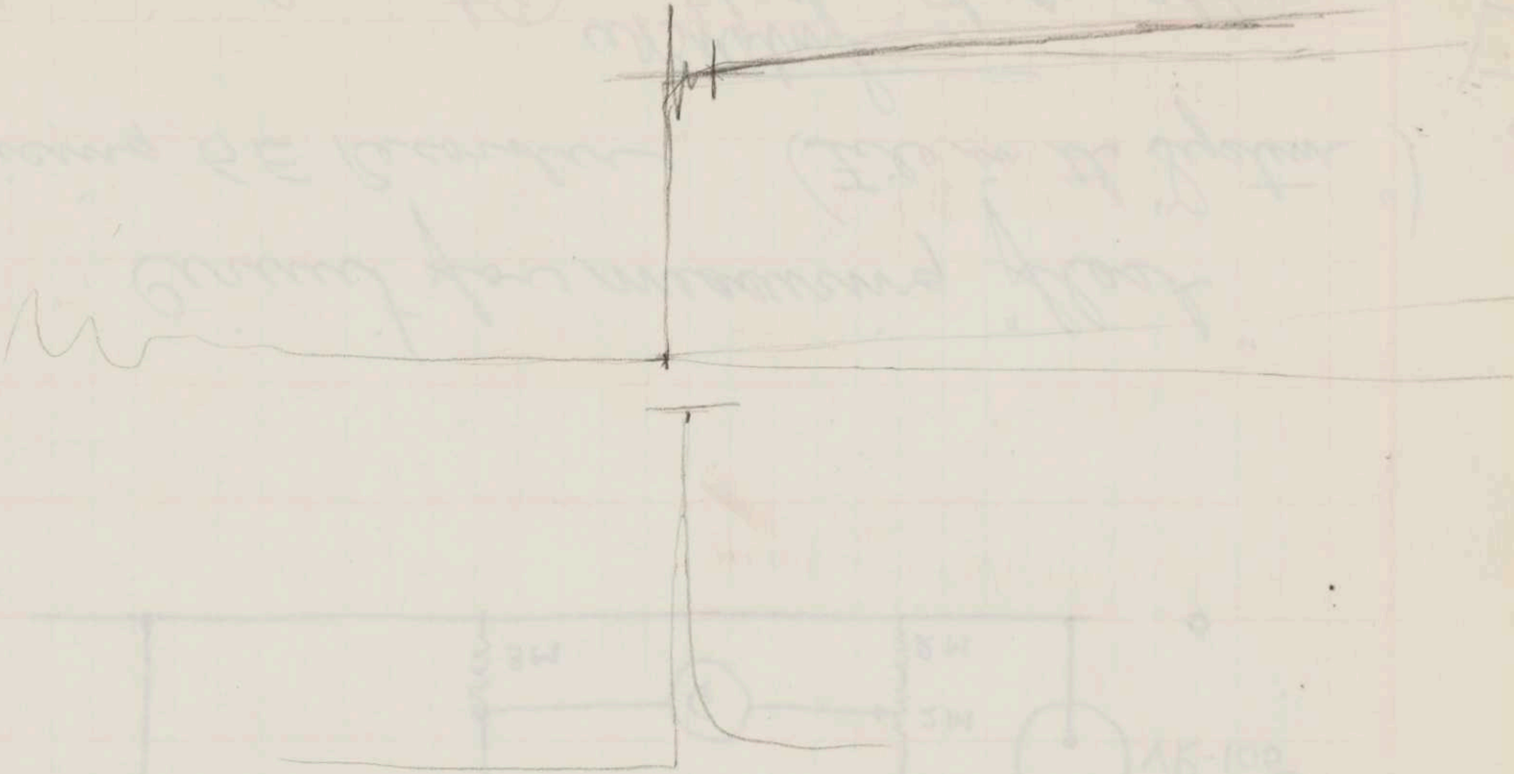
Test by observing current (G) with switch open after closing it. If OK will try out with mult.



Equations for T network

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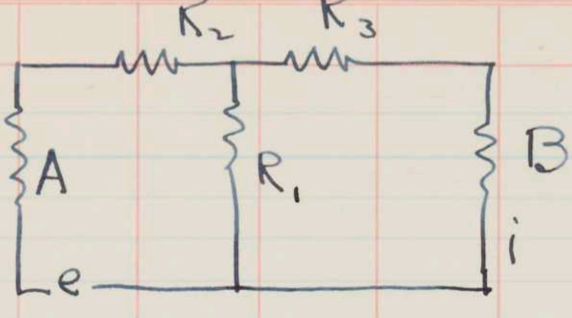
①



when $R_2 = 0 = R_3$ & $R_1 = \infty$

Current through B =

$$i_0 = \frac{e}{A+B}$$

Case IV (general.

(drop over R_1) = $e_1 = i\,(R_3 + B)$

$$e_1 = \frac{e\,\dfrac{(B+R_3)R_1}{R_1+R_3+B}}{A+R_2+\dfrac{R_1(B+R_3)}{R_1+R_3+B}} = i\,(R_3+B)$$

$$\therefore\ i = \frac{e\,\dfrac{R_1}{R_1+R_3+B}}{A+R_2+\dfrac{R_1(B+R_3)}{R_1+R_3+B}}$$

$$\frac{i}{i_0} = S = \frac{\dfrac{R_1(A+B)}{R_1+R_3+B}}{A+R_2+\dfrac{R_1(B+R_3)}{R_1+R_3+B}}$$

3/7/42
2

$$B = R_2 + \frac{R_1(R_3+B)}{R_1+R_3+B}$$

$$A = R_3 + \frac{R_1(R_2+A)}{R_1+R_2+A}$$

$$S = \frac{R_1(A+B)}{(R_1+R_3+B)(A+R_2) + R_1(B+R_3)}$$

$$= \frac{R_1(A+B)}{R_1(A+B+R_2+R_3) + (B+R_3)(A+R_2)}$$

$$\cancel{R_1(B - R_3 = B \cdot R)}$$

$$\cancel{R_1 B} - R_1R_2 - R_1R_3 - \cancel{R_1 B} = -B^2 - BR_3 + R_2R_3 + BR_2$$

$$R_1(R_2+R_3) = B^2 + BR_3 - BR_2 - R_2R_3$$

$$R_1 = \frac{B^2 + BR_3 - BR_2 - R_2R_3}{R_2+R_3}$$

From 2

$$R_1 = \frac{(B-R_2)(B+R_3)}{R_2+R_3}$$

$$(B-R_2)(B+R_3) = (A-R_3)(A+R_2)$$

$$-R_2(B+R_3) - R_2(A-R_3) = -B(B+R_3) + A(A-R_3)$$

$$R_2(A+B) = -B^2 - BR_3 + A^2 - AR_3$$

$$= A^2 - B^2 - R_3(A+B)$$

$$R_2 = A - B - R_3$$

$$R_2 + R_3 = A - B$$

$$R_1 = \frac{(B-R_2)(B+R_3)}{A-B} = \frac{B^2 + B(R_3-R_2) - R_2R_3}{A-B}$$

$$R_3 - R_2 = A - B - 2R_2$$

$$R_2R_3 = (A-B)R_2 - R_2^2 = (A-B)R_3 - R_3^2$$

$$R_1 = \frac{B^2 + B(A-B) - 2BR_2 - (A-B)R_2 - R_2^2}{A-B}$$

3/7/42
(4)

$$R_1 = \frac{AB - (A+B)R_2 - R_2^2}{A-B}$$

$$Y = \frac{(R_3+B)R_1}{R_1+R_3+B} = \frac{R_1}{1 + \frac{R_1}{R_3+B}}$$

$$S = \frac{\dfrac{R_1(A+B)}{1+\frac{R_1}{R_3+B}}}{(R_3+B)\left(\dfrac{R_1}{1+\frac{R_1}{R_3+B}} + R_2 + A\right)}$$

$$S = \frac{R_1(A+B)}{1+\frac{R_1}{R_3+B}} \qquad \frac{R_1(A+B)}{(R_3+B+R_1)\left(\dfrac{R_1}{1+\frac{R_1}{R_3+B}} + A + A - B - R_3\right)}$$

$$S = \frac{R_1(A+B)}{(R_3+B+R_1)\left(\dfrac{1}{\frac{1}{R_1}+\frac{1}{R_3+B}} + 2A - B - R_3\right)}$$

$$\cancel{AR_1} + AR_2 + A^2 = R_1R_3 + R_2R_3 + AR_3 + R_1R_2 + \cancel{R_1A}$$

$$R_1(R_2 + R_3) = -AR_3 + AR_2 + A^2 - R_2R_3$$

$$R_1 = \frac{A^2 + AR_2 - AR_3 - R_2R_3}{R_2 + R_3} = \frac{B^2 + BR_3 - BR_2 - R_2R_3}{R_2 + R_3}$$

$$A^2 + AR_2 - AR_3 = B^2 + BR_3 - BR_2$$

$$A^2 - B^2 = -(A+B)R_2 + (A+B)R_3$$

$$A - B = R_3 - R_2$$

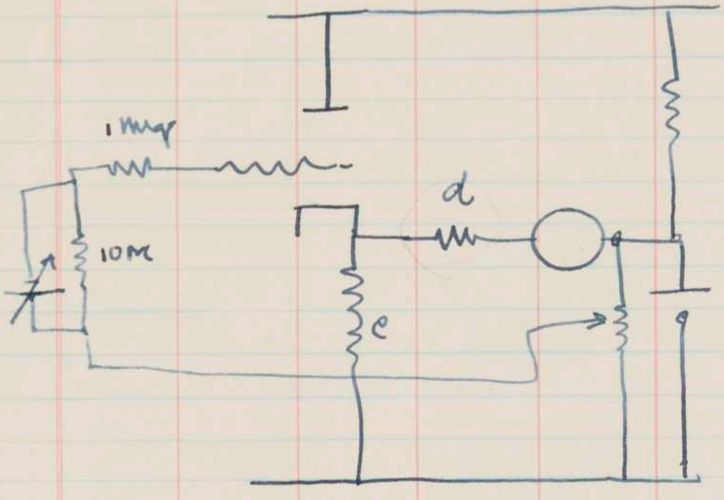
$$R_3 = R_2 + A - B$$

$$R_1 = \frac{\cancel{B^2} + \cancel{BR_2} + BA - \cancel{B^2} - \cancel{BR_2} - R_2^2 - AR_2 + BR_2}{2R_2 + A - B}$$

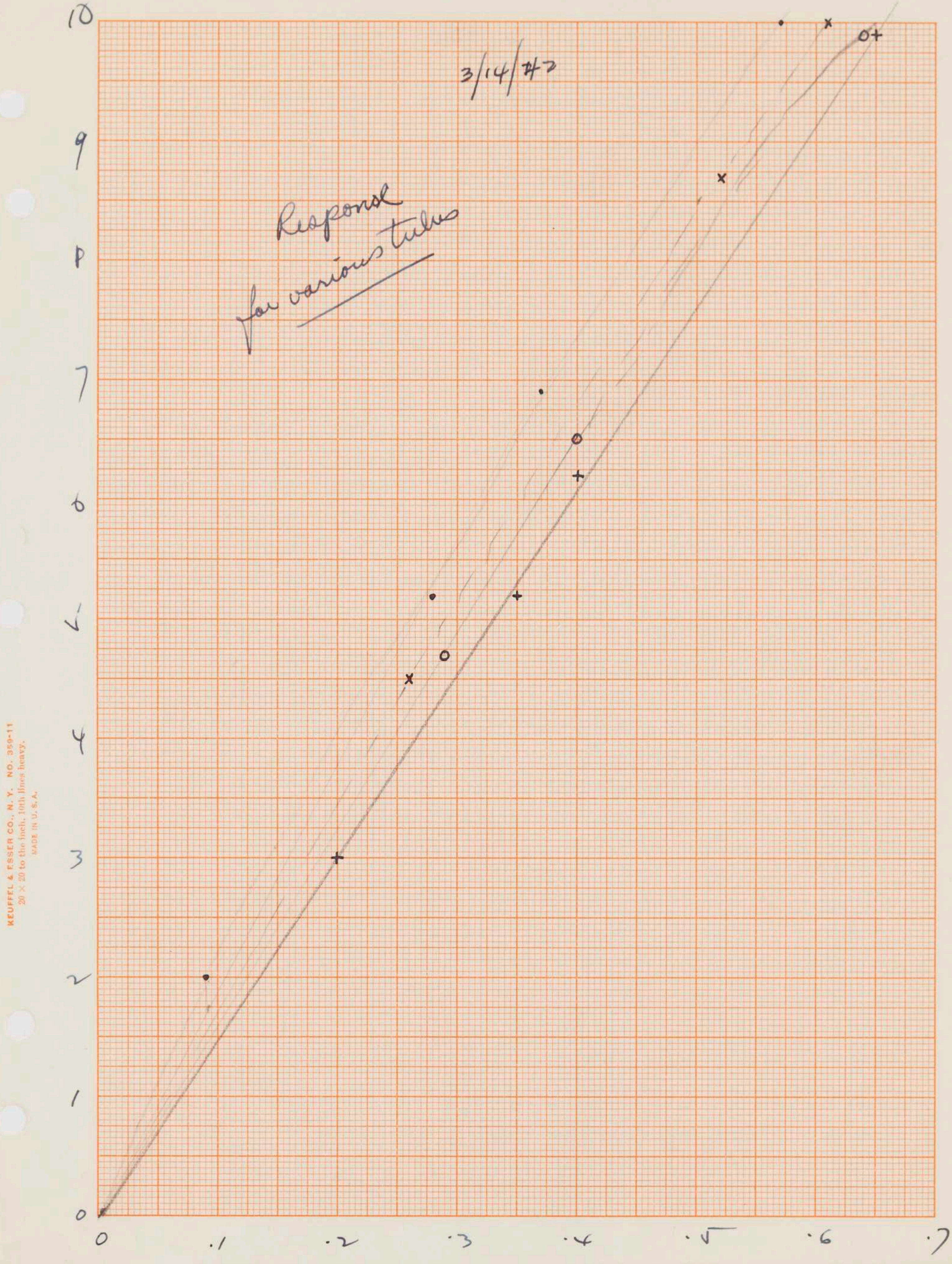
$$= \frac{B(A + R_2) - R_2(A + R_2)}{2R_2 + A - B} = \frac{(A+R_2)(B-R_2)}{(A+R_2) - (B-R_2)}$$

$$R_1 = \frac{1}{\frac{1}{(B-R_2)} - \frac{1}{(A+R_2)}} \quad \therefore \quad \frac{1}{R_1} = \frac{1}{(B-R_2)} - \frac{1}{(A+R_2)}$$

3/14/42



Tube	Cathode c	d	Bias	V	D	Vib	ip
7F7	100M	500	-2.7	.28	5.2	.09	
				.09	2.0		
				.37	6.9		
				.57	10.0		
							1
X	30	886	-1.6	.26	4.5	08	3
				.52	8.7		
				.61	10.0		
6SN7	8	1180	-6.8	.35	5.2		12.5
⊕				.2	3.0		
				.4	6.2		
				.65	9.9		
6SF5	100M		-1.43	~~.35~~	~~5.2~~		1
0		980		.29	4.7		
				.4	6.5		
				.64	9.9		


3/14/42
Response for various tubes
10
9
8
7
6
5
4
3
2
1
0
0
.1
.2
.3
.4
.5
.6
.7
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20 × 20 to the inch, 10th lines heavy.
MADE IN U. S. A.

Ref: WBN, J. of Frank. Inst. 209, 287 (1930)
P. K. McElroy: Proc. I.R.E. 23 213 (1935)

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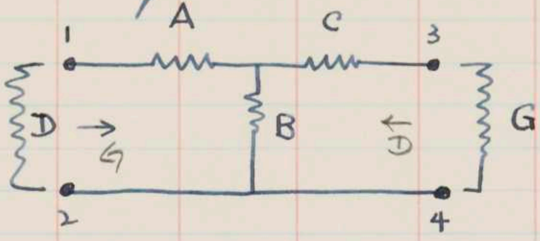
①

This is a rewrite of some calculations of 3/8/42 to make results more concise.

I Problem of control circuit



conditions:

Look in at 1-2 and always measure G when terminated in G

Look in at 3-4 and always see D when terminated in D.

$$G = A + \frac{B(C+G)}{B+C+G} \qquad (1)$$

$$D = C + \frac{B(A+D)}{A+B+D} \qquad (2)$$

~~Call~~ Take current in A to be i_0 then

See Eq 13

$$i_0 B = i_g (B+C+G)$$

$$\frac{i_0}{i_g} = 1 + \frac{C+G}{B} = k \qquad (3)$$

define $\frac{i_0}{i_g} \equiv k$ this is current attenuation ratio (4)

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(2)

Skip to 5a and 9

With equations (1) (2) and (3) values of A, B, and C may be determined for set values of D, G and k.

$$B = \frac{C + G}{k - 1} \qquad (5)$$

Subtract ~~add~~ equations (1) and (2) as follows:-

$$0 = (D - G) - (C - A) + B\left[\frac{C + G}{B + C + G} - \frac{A + D}{A + B + D}\right] \qquad (6)$$

$$[\,- \cdot -\,] = \begin{array}{l} AC + BC + CD + AG + BG + DG \\ \underline{-AC \quad\; -CD - AG \quad\; -DG - AB - BD} \\ \quad +BC \; \cancel{A} \quad\; +BG \quad\; -AB - BD \end{array}$$

$$= -B\left[D - G - C + A\right]$$

$$0 = (D - G - C + A)\left(1 - \frac{B^2}{(B + C + G)(A + B + D)}\right) \qquad (7)$$

Either or both factors are zero

$$(D - G) = (C - A) \qquad (8)$$

since inspection shows that with all positive values of A, B, C, + D this can not be zero.

A better way of obtaining $\underline{8}$ is as follows

G may always be changed to D if at the same time C is changed to A.

$$\therefore \quad B = \frac{A + D}{k - 1} \qquad (5a)$$

and it follows that

$$A + D = C + G \qquad (9)$$

This the same as $\underline{8}$ above.

An emf in the D circuit would give

$$i_o = \frac{e}{D+G} \quad \text{or} \quad i_o(D+G) = e \qquad (10)$$

with this

$$e - i_o(D+A) = i_g(C+G) \qquad (11)$$

$$\therefore \; i_o(\cancel{D} + G - \cancel{D} - A) = i_g(C+G) \qquad (12)$$

$$\frac{i_o}{i_g} \equiv k = \frac{C+G}{G-A} = \frac{D+A}{G-A} = \frac{G+C}{D-C} \qquad (13)$$

Solving eq. (13)

$$kG - kA = D + A$$

$$A = \frac{kG - D}{k+1} = G\,\frac{k - \frac{D}{G}}{k+1} \qquad (14)$$

This shows that there is an impossible range in A for $k < \frac{D}{G}$

For real values of A; $k \geq \frac{D}{G}$ (15)

$$C = D\,\frac{k - \frac{G}{D}}{k+1} \qquad (16)$$

If A has been determined use (9)

$$C = A + (D - G) \qquad (17)$$

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5

Start with (5a)
and use (14)

$$B = \frac{A+D}{k-1} = \frac{\frac{kG-D}{k+1}+D}{k-1} \qquad (18)$$

$$= \frac{kG - \cancel{D} + kD + \cancel{D}}{k^2-1} = G\,\frac{k\left(1+\frac{D}{G}\right)}{k^2-1} \qquad (19)$$

$$B = G\,\frac{k\left(1+\frac{D}{G}\right)}{k^2-1} \qquad (19)$$

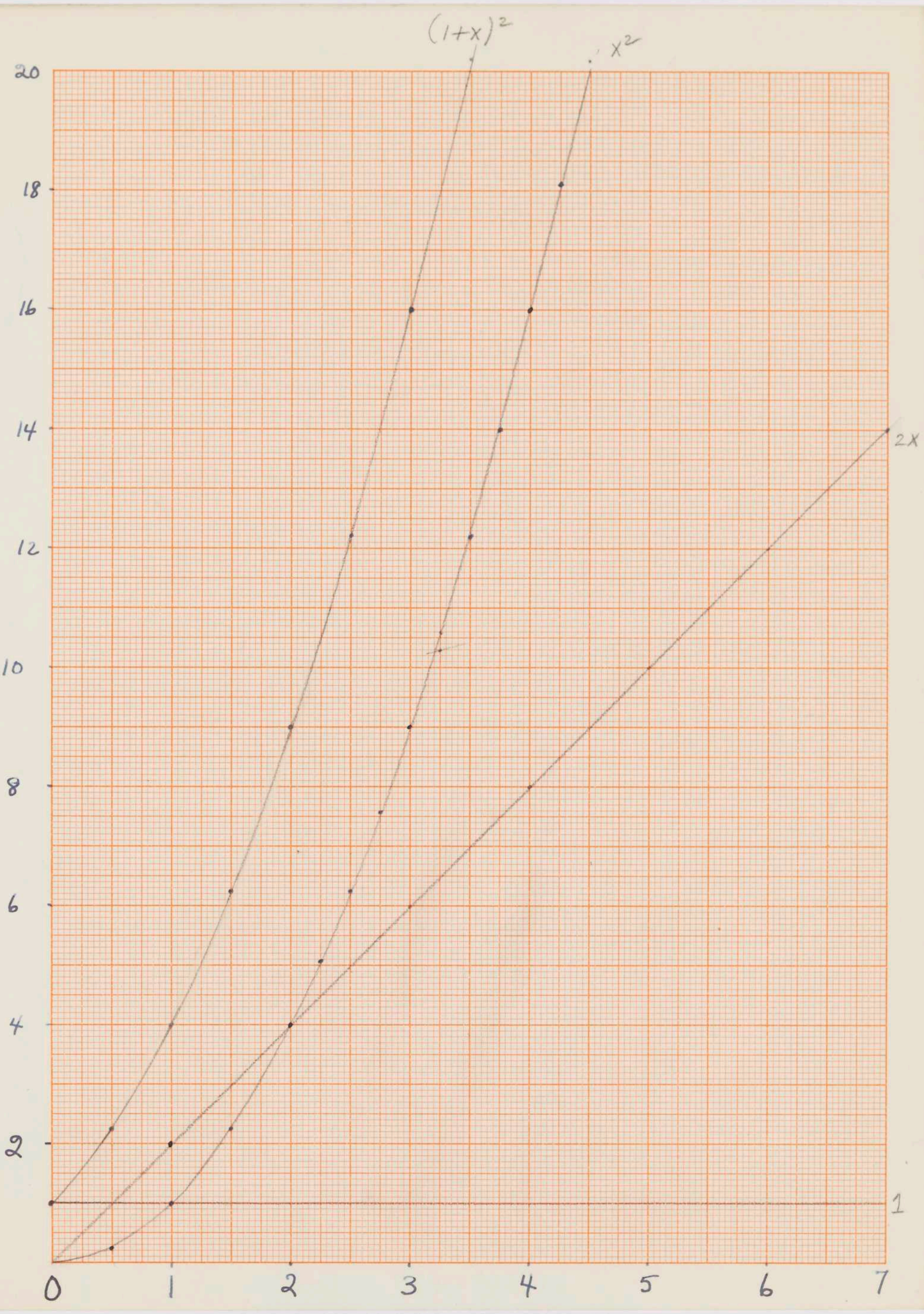
Need table for given $\frac{D}{G}$

$\frac{D}{G} = 2$

$B = G\,\frac{3k}{k^2-1}$ $\qquad$ $A = G\,\frac{k-2}{k+1}$

k	k	$k-2$	$k+1$	—	$3k$	k^2-1	—	A	B	C
	1							0	∞	0
$\sqrt{10}$	3.162	1.162	4.162	.2795	9.486	9	1.053	558	2108	2558
10	10	8	11	.728	30	99	.303	1454	606	3454
$\sqrt{1000}$	31.62	29.62	32.62	.908	94.86	999	.095	1814	190	3814
100	100	98	101	.972	300	9999		1944	60	3944

Could use $\frac{k}{k^2-1}$ table


(1+x)^2
x^2
2x
1
20
18
16
14
12
10
8
6
4
2
0
1
2
3
4
5
6
7

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6

Table for

$D = 5000$ $\frac{D}{G} = 2.5$

$G = 2000$

k	$k-2.5$		—	$3.5k$	k^2-1	—	A	B	C
1									
$\sqrt{10}$	.662	4.162	.1592	11.06	9	.123	318.5	2460	3318
10	7.5	11	.682	35	99	.3535	1364	707	4364
$\sqrt{1000}$	29.12	32.62	.893	110.6	999	.1107	1785	221.3	4785
100	97.5	101	.9655	350	9999	.035	1931	70.0	4931

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1

$$i_p = \frac{1}{r_p}(\mu e_g + e_p - \varepsilon)$$

$$e_g = V_g - i_k K$$

$$e_p = V_p - i_k K$$

$$i_p = i_k + I_g$$

$$I_G G = V_R - i_k K \qquad\qquad i_k K = V_R - I_G G$$

Solve for I_G as a function of V_g and also consider case of variation in V_R

$$r_p(i_k + I_G) = \mu(V_g - i_k K) + V_p - i_k K - \varepsilon$$

$$r_p I_G = \mu V_g - i_k(r_p + \mu K + K) + V_p - \varepsilon$$

$$-i_k K\left(1 + \mu + \frac{r_p}{K}\right)$$

$$r_p I_G = \mu V_g - V_R\left(1 + \mu + \frac{r_p}{K}\right) + I_G G\left(1 + \mu + \frac{r_p}{K}\right) + V_p - \varepsilon$$

$$I_G\left(r_p - G\left(1 + \mu + \frac{r_p}{K}\right)\right) = \mu V_g - V_R\left(1 + \mu + \frac{r_p}{K}\right) + V_p - \varepsilon$$

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②

$$\frac{dI_G}{dV_g} = \frac{\mu}{r_p - G\left(1+\mu+\frac{r_p}{K}\right)} = \frac{g_m}{1-\frac{G}{r_p}\left(1+\mu+\frac{r_p}{K}\right)}$$

$$= \frac{\frac{\mu}{r_p}}{1-\frac{G}{r_p}\left(1+\mu+\frac{r_p}{K}\right)}$$

Take $D = \frac{r_p}{\mu} = \frac{1}{g_m}$

$$\frac{dI_G}{dV_g} = \frac{\frac{1}{D}}{1-\frac{G}{D}\left(\frac{1}{\mu}+1+\frac{D}{K}\right)}$$

with $D = G$

$$\frac{dI_G}{dV_g} = \frac{\frac{1}{G}}{-\frac{1}{\mu} - \frac{G}{K}} = \frac{g_m}{-\frac{1}{\mu} - \frac{1}{K g_m}}$$

$$= \frac{g_m}{-\frac{1}{\mu} - \frac{1}{K}\frac{r_p}{\mu}}$$

$$= -\frac{g_m}{\frac{1}{\mu}\left(1+\frac{r_p}{K}\right)}$$

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$$\frac{dI_o}{dV_R} = \frac{-\left(1+\mu+\frac{r_p}{k}\right)}{r_p - G\left(1+\mu+\frac{r_p}{k}\right)} = \frac{1}{G - \frac{r_p}{1+\mu+\frac{r_p}{k}}}$$

$$R_{VR} = G - \frac{r_p}{1+\mu+\frac{r_p}{k}}$$

$$\cancel{\frac{1}{\frac{1}{r_p}}}$$

$$\frac{1}{\frac{1}{r_p}+g_m+\frac{1}{k}} = \text{output impedance}$$

$$\frac{3500}{1+20+\frac{1800}{8000}} = \cancel{85} \quad 165\,\omega$$

1 .225

21.22

$R_p = 1800$

$$\begin{cases} i_p = \frac{1}{r_p}(\mu e_g + e_p - \varepsilon) \\ e_g = V_g - V_K \\ V_K = V_p' - e_p \\ i_p = i_K - i_G \quad \text{or} \quad i_K = i_p + i_G \\ i_G(c + g) + i_p c = V_R \end{cases}$$

Wanted $\dfrac{di_G}{dV_g} = ?$

$$\frac{di_p}{dV_g} = \frac{\mu}{r_p}\frac{de_g}{dV_g} + \frac{1}{r}\frac{de_p}{dV_g}$$

$$\frac{de_g}{dV_g} = 1 - \frac{dV_K}{dV_g}$$

$$\frac{dv_K}{dv_g} = - \frac{de_p}{dv_g}$$

$$\frac{di_p}{dv_g} = \frac{di_K}{dv_g} - \frac{di_G}{dv_g}$$

$$\frac{di_G}{dv_g}\left(\frac{c+g}{c}\right) + \frac{di_p}{dv_g} = 0$$

$$\frac{di_G}{dv_g}\left(1 + \frac{c+g}{c}\right) = \frac{di_K}{dv_g}$$

$$\frac{di_G}{dv_g} = \frac{di_K}{dv_g} - \frac{\mu}{r_p}\frac{de_g}{dv_g} - \frac{1}{r}\frac{de_p}{dv_g}$$

$$\frac{di_G}{dv_g}\left(\frac{c+g}{c}\right) = \frac{\mu \cancel{de}}{r_p} e_g' + \frac{1}{r_p} e_p' \qquad (1)$$

$$e_g' = 1 + e_p' \qquad (2)$$

$$e_p = V_p - 0 - V_R + i_G g$$

$$\cancel{V_R - i_G g + e_p - V_p = 0}$$

$$\cancel{e_p = V_p - V_p + i_G g}$$

$$e_p' = g\frac{di_G}{dv_g} \qquad (3)$$

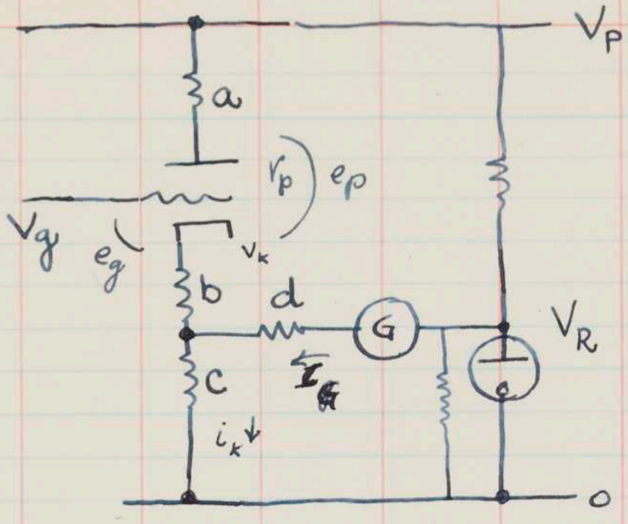
$$\frac{di_g}{dv_g}\left(\frac{c+g}{c}\right) = g_m + g\, g_m \frac{di_g}{dv_g} + \frac{g}{r_p}\frac{di_g}{dv_g}$$

$$\frac{di_g}{dv_g}\left\{\frac{c+g}{c} - \frac{g\mu}{r_p} - \frac{g}{r_p}\right\} = g_m$$

$$S = \frac{g_m}{1 + \frac{g}{C} - \frac{g}{r_p}(\mu+1)}$$

?

$$= \frac{g_m}{1 + g\left(\frac{1}{c} + \frac{\mu+1}{r_p}\right)}$$



$$i_p = \frac{1}{r_p}\left(\mu e_g + e_p - \varepsilon\right) \qquad (1)$$

$$e_g = V_g - V_K \quad = \quad V_g - V_p + i_p a + e_p \quad {}^{(3+2)} \qquad (2)$$

$$V_K = V_p - i_p a - e_p \qquad (3)$$

$$i_p = i_K - i_g \qquad\qquad i_k c = i_p c + i_g c \qquad (4)$$

$$i_g(d+g) + i_k c = V_R \qquad (5)$$

$$i_g(c+d+g) + i_p c = V_R \qquad (4+5) \qquad (6)$$

$$i_p = \frac{\mu}{r_p}\left(V_g - V_p + i_p a + e_p\right) + \frac{e_p}{r_p} - \frac{\varepsilon}{r_p} \qquad (1+2a) \qquad (7)$$

$$e_p = V_p - i_p(a+b) - V_R + i_g g \qquad (8)$$

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(5)

$$i_p = \frac{\mu}{r_p}\left(V_g - \cancel{V_p} + i_p a + \cancel{V_p} - i_p(a+b) - V_R + i_g g\right) + \frac{V_p}{r_p} - \frac{i_p}{r_p}(a+b) - \frac{V_R}{r_p} + \frac{i_g}{r_p}g - \frac{\varepsilon}{r_p} \qquad (9)$$

$$c\, i_p\left(1 + \frac{\mu b}{r_p} + \frac{a+b}{r_p}\right) = c\frac{\mu}{r_p}\left(V_g - V_R + i_g g\right) + c\,\frac{V_p - V_R - \varepsilon}{r_p} + \frac{i_g g c}{r_p} \qquad (10)$$

$$\left[V_R - i_g(c+d+g)\right]\left[1 + \frac{\mu b}{r_p} + \frac{a+b}{r_p}\right] = \quad \cdots \quad \cdots \quad \cdots \qquad (11)$$

$$-i_g\left[(c+d+g)\left(1 + \frac{\mu b + a + b}{r_p}\right) + \frac{\mu}{r_p}cg + \frac{cg}{r_p}\right] = -V_R\left[1 + \frac{a + b(\mu+1)}{r_p}\right] + \qquad (12)$$

$$+ \frac{\mu}{r_p}c\left[V_g - V_R\right] + c\,\frac{V_p - V_R - \varepsilon}{r_p}$$

Sensitivity is $\dfrac{di_g}{dV_g}$

$$\frac{di_g}{dV_g} = \frac{\frac{\mu}{r_p}c}{(c+d+g)\left(1 + \frac{a+b(\mu+1)}{r_p}\right) + \frac{cg}{r_p}(\mu+1)} \qquad (13)$$

$$= \frac{g_m}{\left(1 + \frac{d+g}{c}\right)\left(1 + \frac{a+b(\mu+1)}{r_p}\right) + \frac{g}{r_p}(\mu+1)} \qquad (14)$$

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Although (14) is general it does not show the limitations put on by the damping condition which are that the resistance looking in at the gal. terminal must be the damping resistance D. and that the current through the galvanometer must be zero at standby.

~~From~~ (12) take $\frac{dV_R}{di_g} = g + D$ (15)

$$\cancel{\frac{dV_R}{di_g}\left[1+\frac{a+b(\mu+1)}{r_p}\right] - (c+d+g)\left(1+\frac{a+b(\mu+1)}{r_p}\right)}$$

$$-\left[(c+d+g)\left(1+\frac{a+b(\mu+1)}{r_p}\right) + \frac{cg}{r_p}(\mu+1)\right] = -\frac{dV_R}{di_g}\left[1+\frac{a+b(\mu+1)}{r_p}\right]$$

$$= \frac{dV_R}{di_g}\left[\frac{\mu}{r_p}c + \frac{c}{r_p}\right] \qquad (16)$$

$$\frac{dV_R}{di_g} = \frac{(c+d+g)\left(1+\frac{a+b(\mu+1)}{r_p}\right) + \frac{cg}{r_p}(\mu+1)}{1+\frac{a+b(\mu+1)}{r_p}+\frac{c(\mu+1)}{r_p}} \qquad (17)$$

$$\frac{dV_R}{di_g} = \frac{c+d+g+\frac{(c+d+g)(a+(\mu+1)b)+cg(\mu+1)}{r_p}}{1+\frac{a+(b+c)(\mu+1)}{r_p}} \qquad (18)$$

3/13/42 (7)

$$\frac{dV_R}{di_g} = \frac{c+d+g+\dfrac{a(c+d+g)+(\mu+1)(bc+bd+bg+cg)}{r_p}}{1+\dfrac{a+(b+c)(\mu+1)}{r_p}} \qquad (19)$$

$$\frac{dV_R}{di_g} - g \equiv D = \frac{c+d+\cancel{g}+\dfrac{a(c+d)+\cancel{ag}+\cancel{(\mu+1)g(b+c)}+(\mu+1)(c+d)b-\cancel{ag}-\cancel{g(b+c)(\mu+1)}}{r_p}-\cancel{g}}{1+\dfrac{\cancel{a+}\;a+(b+c)(\mu+1)}{r_p}} \qquad (20)$$

$$D = \frac{c+d+\dfrac{a(c+d)+(\mu+1)(c+d)b}{r_p}}{1+\dfrac{a+(b+c)(\mu+1)}{r_p}} \qquad (21)$$

$$D = \frac{1+\dfrac{a+b(\mu+1)}{r_p}}{\dfrac{1}{c+d}+\dfrac{a+(b+c)(\mu+1)}{(c+d)\,r_p}} \qquad (22)$$

To check set a and b, d = 0

$$D = \frac{1}{\dfrac{1}{c}+\dfrac{\mu+1}{r_p}} \qquad (23)$$

which checks ok

Start again with fig on p ⊖
take a and b = 0

$$i_p = \frac{1}{r_p}(\mu e_g + e_p - \varepsilon)$$

$$e_g = V_g - V_k \qquad = V_g - (i_p + i_g)c$$

$$= V_g - V_p + e_p \qquad = \cancel{V_g - V_p + V_p - V_k}$$

$\cancel{-i_p a}$

$$V_k = V_p - e_p = c\, i_k \quad \| \; e_p = V_p - V_k)|$$

$$i_p = i_k - i_g \qquad i_k c = i_p c + i_g c = V_k$$

$$i_g(d+g) + i_k c = V_R$$

$$i_g(c+d+g) + i_p c = V_R$$

$\cancel{i_p = \frac{1}{r_p}}$

$$r_p i_p = \mu(V_g \cancel{- V_p} \cancel{+ V_p} - i_p c - i_g c)$$

$$+ V_p - i_p c - i_g c - \varepsilon$$

$$i_p(r_p + \mu c + c) = -i_g(\mu+1)c + \mu V_g + V_p - \varepsilon$$

$$i_p(c) \qquad = V_R - i_g(c+d+g)$$

$$V_R\left(\frac{r_p}{c}+\mu+1\right) - i_g\left\{r_p + r_p\frac{d+g}{c} - c(\mu+1)\right\} = \mu V_g + V_p - \varepsilon$$

$$i_g\, r_p\underbrace{\left\{1+\frac{d+g}{c} - \frac{c(\mu+1)}{r_p}\right\}}_{A} = V_R\left(\frac{r_p}{c}+\mu+1\right) - \mu V_g - V_p + \varepsilon$$

$$-\frac{di_g}{dV_g} = \frac{\mu}{r_p\underbrace{\left\{1+\frac{d+g}{c} - \frac{c(\mu+1)}{r_p}\right\}}_{A}} = \frac{g_m}{1+\frac{d+g}{c} - \frac{c(\mu+1)}{r_p}}$$

Compute

$$\frac{di_g}{dV_R} = \frac{1}{D+g} = \frac{\cancel{rA}\ \frac{r_p}{c}+\mu+1}{r_p\,A}$$

$$D = \frac{r_p\,A}{\frac{r_p}{c}+\mu+1} - g = \frac{r_p A - g\left(\frac{r_p}{c}+\mu+1\right)}{\frac{r_p}{c}+\mu+1}$$

$$D = \frac{\frac{S}{\mu} - g\left(\frac{r_p}{c}+\mu+1\right)}{\frac{r_p}{c}+\mu+1} = \frac{S}{\mu\left(\frac{r_p}{c}+\mu+1\right)} - g$$

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$$i_p = \frac{\mu}{r_p} e_g + \frac{e_p}{r_p} - \frac{\varepsilon}{r_p}$$

$$e_g = V_g - V_k$$

$$e_p = V_p - V_k - i_p a$$

$$V_k = i_k c = i_p c + i_g c$$

$$i_p (r_p + a) = \mu (V_g - V_k) + V_p - V_k \cancel{i_p a} - \varepsilon$$

$$= \mu (V_g) - V_k(\mu + 1) + V_p - \varepsilon$$

$$(r_p + a) \frac{di_p}{dV_g} = \mu - \frac{dV_k}{dV_g}(\mu + 1)$$

$$\frac{1}{c} \frac{dV_k}{dV_g} = \frac{di_p}{dV_g}\cancel{c} + \frac{di_g}{dV_g}\cancel{c} \qquad \left(\frac{di_p}{dV_g}\right) = \frac{1}{c}\frac{dV_k}{dV_g} - \frac{di_g}{dV_g}$$

$$(r_p + a)\left(\frac{1}{c}\frac{dV_k}{dV_g} - \frac{di_g}{dV_g}\right) = \mu - \frac{dV_k}{dV_g}(\mu + 1)$$

$$\frac{di_g}{dV_g} = -\frac{\mu}{r_p + a} + \frac{dV_k}{dV_g}\left\{\frac{\mu + 1}{r + a} + \frac{1}{c}\right\}$$

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"

$$g\, i_g = V_R - V_K$$

$$g \frac{di_g}{dV_K} = -1 \qquad \text{or} \qquad \frac{dV_K}{di_g} = -g$$

$$\frac{dV_K}{di_g} \times \frac{di_g}{dV_g} = \frac{dV_K}{dV_g} = -g \frac{di_g}{dV_g} = -gS$$

$$S = -\frac{\mu}{r_p + a} - gS\left\{\frac{\mu+1}{r+a} + \frac{1}{c}\right\}$$

$$S = -\frac{\dfrac{\mu}{r_p + a}}{1 + g\left\{\dfrac{\mu+1}{r+a} + \dfrac{1}{c}\right\}}$$

$$g \frac{di_g}{dV_R} = 1 - \frac{dV_K}{dV_R}$$

$$\frac{di_g}{dV_R} = \frac{1}{g + Z}$$

where Z = effective terminating resistance determining the damping of galv.

$$i_p(r+a) = \mu V_g - V_K(\mu+1) + V_p - \varepsilon$$

$$g(i_g) = V_R - V_K \qquad V_K = V_R - g i_g$$

$$i_p(r+a) = \mu V_g - (V_R - g i_g)(\mu+1) + V_p - \varepsilon$$

$$i_K c = V_R - g i_g$$

$$i_K c = i_p c + i_g c$$

$$i_p c = V_R - i_g(c+g)$$

$$i_p(r+a) = \frac{r+a}{c}\left(V_R - i_g(c+g)\right) = \mu V_g - (V_R - g i_g)(\mu+1) + V_p - \varepsilon$$

$$i_g\left[g(\mu+1) + \frac{(c+g)(r+a)}{c}\right] = -\mu V_g + V_R\left[\frac{r+a}{c} + \mu + 1\right] - V_p + \varepsilon$$

divide by $(r+a)$

$$i_g\left[\frac{g}{r+a}(\mu+1) + \frac{c+g}{c}\right] = -\frac{\mu}{r+a}V_g + V_R\left[\frac{1}{c} + \frac{\mu+1}{r+a}\right] - \frac{V_p - \varepsilon}{r+a}$$

$$S = \left[\frac{di_g}{dV_g}\right]_{V_R = \text{const}} = -\frac{\dfrac{\mu}{(r+a)}}{\left[1 + \cancel{g+}\, g\left[\dfrac{1}{c} + \dfrac{\mu+1}{\underset{R}{r+a}}\right]\right]}$$

this checks with result on (11)

$$\left[\frac{di_g}{dV_R}\right]_{V_g=\text{const}} = \frac{\left[\frac{1}{c}+\frac{\mu+1}{r+a}\right]}{1+g\left[\frac{1}{c}+\frac{\mu+1}{r+a}\right]}$$

$$= \frac{1}{g+\left[\frac{1}{c}+\frac{\mu+1}{r+a}\right]^{-1}} = \frac{1}{g+Z}$$

$$\therefore \frac{1}{Z} = \frac{1}{c}+\frac{\mu+1}{r_p+a}$$

or $\frac{1}{Z} \doteq \frac{\mu+1}{r_p+a}$

$a \doteq Z(\mu+1) - r_p$

It follows from this that

$$S = -\frac{\frac{\mu}{r_p+a}}{1+\frac{g}{Z}} \doteq$$

where $Z = \cancel{\frac{c+r_p+a}{\quad}}\ \frac{1}{\frac{1}{c}+\frac{1}{r_p+a}+\frac{\mu}{r_p+a}}$

Take actual gal res to be ~~d~~ G

then $g = d + G$ and $Z + d = D$ = crit damping res

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$$\frac{g}{Z} = \frac{G+d}{D-d}$$

$$S = \frac{\dfrac{\mu}{r_p+a}}{1 + \dfrac{G+d}{D-d}}$$

$$\frac{1}{D-d} = \frac{1}{c} + \frac{1}{r_p+a} + g_m'$$

$$g_m' = \frac{1}{D-d} - \frac{1}{c} - \frac{1}{r_p+a}$$

$$S = \frac{\dfrac{1}{D-d} - \dfrac{1}{c} - \dfrac{1}{r_p+a}}{1 + \dfrac{G+d}{D-d}}$$

$$= \frac{\cancel{1 - cD + cd}}{\qquad}$$

$$= \frac{\cancel{r_p+a}\; 1 - \dfrac{D-d}{c} - \dfrac{D-d}{r_p+a}}{D-d+G+d}$$

$$S = \frac{1 - (D-d)\left(\frac{1}{c} + \frac{1}{r_p + a}\right)}{D + G}$$

$$S = \frac{1 - \cancel{2000}\left(\frac{1}{20} + \frac{1}{\cancel{16} + 14}\right)}{\cancel{1+} \; 4000}$$

$$= \frac{1 - 2\left(\frac{\cancel{30}\,50}{600}\right)}{4000} = \frac{1 - .16}{4000} = 210 \ \mu a/\text{volt}$$

Max "voltage" sensitivity possible is

$S = \frac{1}{D+G}$ and this limit comes

when $(D-d)\left(\frac{1}{c} + \frac{1}{r_p + a}\right) \doteq 0$

$$\frac{D-d}{c} + \frac{D-d}{r_p + a}$$

The range in d is from 0 to D.
The above comes logically from the fact that the "gain" of a cathode follower is ~~generally~~ less than unity.

3/13/42

20

$$K = \frac{1}{1 + g_m \dfrac{c}{1 + \dfrac{a+c}{r_p}}} = \frac{1}{1 + g_m \dfrac{1}{\dfrac{1}{c} + \dfrac{a+c}{r_p c}}}$$

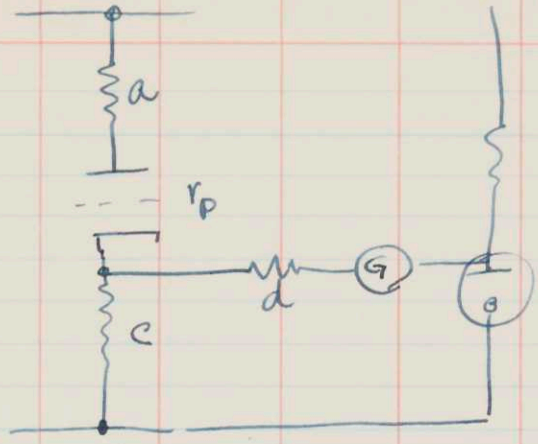
$$= \frac{1}{1 + g_m \dfrac{r_p c}{r_p + a + c}}$$

$$\frac{1}{K} = 1 + g_m \frac{r_p c}{r_p + a + c}$$

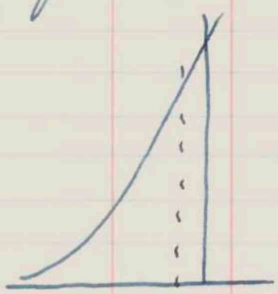
$$\cancel{\frac{1}{K} - 1 = g_m \frac{1}{\frac{1}{c} + \frac{1}{r_p} + \frac{a}{r_p c}}}$$

$$\frac{1}{c}\left(1 + \frac{a}{r_p}\right) + \frac{1}{r_p}$$

$\underline{a}$ of the order of $\underline{r_p}$ or less and c as large as possible makes for max sens.



What considerations determine the proportioning of a, c, d and r_p



1) grid bias should be =to or neg. with respect to floating potential

2) this gives about lowest value of r_p and highest current for good operating range where signals always make grid move in negative direction.

3) The higher the current the lower the value of c for the balance condition.

4) For a given stand-by plate voltage and current the higher the line voltage the higher the value of "a" possible.

How do the resistances d and a effect the damping?

$$D = Z + d \quad = \text{true damping res needed.}$$

If damping is to remain unchange then $dZ = -d(d)$

$$\frac{dZ}{da} = ?$$

$$dZ = -Z^2 \, d\left(\frac{1}{Z}\right)$$

$$\frac{1}{Z} = \frac{1}{C} + \frac{(1+\mu)}{r_p + a}$$

$$\frac{d\left(\frac{1}{Z}\right)}{da} = -\frac{1+\mu}{(r_p+a)^2}$$

$$\therefore \frac{dZ}{da} = \frac{1}{\left(\frac{1}{C} + \frac{1+\mu}{r_p+a}\right)^2} \cdot \frac{1+\mu}{(r_p+a)^2} = \frac{(1+\mu)C^2}{(r_p + a + C(1+\mu))^2}$$

$$\frac{dz}{da} = \frac{\frac{1}{(1+\mu)}}{\left\{1 + \frac{r_p + a}{c(1+\mu)}\right\}^2}$$

$$\doteq \left(\frac{1}{1+\mu}\right)\left(1 - 2\frac{r_p + a}{c(1+\mu)}\right)$$

This indicates that the addition approx ~~of~~ $(1+\mu)\,d$ as plate resistance is just as effective as adding d to correct the damping to critical value.

This is true as long as

$$2\,\frac{r_p + a}{c(1+\mu)} \ll 1$$

If $c = a = r_p$ then correction factor is $\frac{4}{1+\mu}$

at a $\mu = 20$ this is $\frac{4}{21} \doteq 0.2$

$\mu = 100$ " " $= .04$

The sensitivity depends on the proportion between d and a for eg on p (15)

Let $K = (D-d)\left(\frac{1}{c} + \frac{1}{r_p+a}\right)$

The smaller K the higher the sensitivity

$$d + Z = D$$

$$d = D - Z$$

$$K = Z\left(\frac{1}{c} + \frac{1}{r_p+a}\right)$$

$$K = \frac{\frac{1}{c} + \frac{1}{r_p+a}}{\frac{1}{c} + \frac{1}{r_p+a} + \frac{\mu}{r_p+a}}$$

$$= \frac{1}{1 + \frac{\cancel{\frac{\mu}{r_p+a}}}{\frac{\cancel{r_p+a+c}}{c(\cancel{r_p}+a)}}}$$

$$= \frac{1}{1 + \frac{\mu c}{r_p + c + a}} = \frac{r + c + a}{r + a + c(\mu+1)}$$

Consider using a 7F7 —
one half of tube.

$\mu = 70$

$r_p = 44\,000$

$g_m = 1600 \times 10^{-6}$

assume $C = 50{,}000$

$$\frac{1}{K} = 1 + 1600 \times \cancel{10^{-6}} \frac{44 \times 50 \times \cancel{10^{6}}}{(94 + a) \times \cancel{10^{3}}}$$

for $a = 0$

$$1 + 1.6 \frac{44 \times 55}{94} = 42$$

$K = .024$ this is only $2\frac{1}{2}$% below max possible.

Take $a =$ so that $Z = 2000$

$$\frac{1}{2} = 500 \times 10^{-6} = 200 \times 10^{-6} + \frac{71 \times 10^{-3}}{44 + a}$$

$$300 \times 10^{-6} = \frac{71 \times 10^{-3}}{44 + a}$$

$$44 + a = \frac{71 \times 10^{-3}}{300 \times 10^{-6}} = \frac{710}{3}$$

$$a = \cancel{44}\ 237 - 44 = \underline{\underline{293\ M}}$$

With the assumed $i_p = 2$ this is too high a voltage drop.

22 7/13/42

$$\frac{1}{Z} = \frac{1}{c} + \frac{1+\mu}{r_p + a}$$

If the drop over $c = \frac{1}{3} V_p$ over tube is same and over $\underline{a}$ the same then

$$a = c$$

$$\frac{1}{2}\ \cancel{500 \times 10}^{-6} = \frac{1}{c} + \frac{1+\mu}{r_p + c}$$

solve for c

$$c(r_p + c) = Z(\cancel{r_p} + c) + cZ(1+\mu)$$

$$c^2 + c(r_p \cancel{+ 2Z} - Z(2+\mu)) = Z r_p$$

$$c^2 + 2c\left(\frac{r_p - Z(2+\mu)}{2}\right) + (\ \ )^2 = 4Z r_p + \frac{[r_p - Z(2+\mu)]^2}{4}$$

$$= \frac{r_p^2 + Z^2(2+\mu)^2 \cancel{+} 2 r_p Z\mu}{4}$$

$$c = -\frac{r_p - Z(2+\mu)}{2} \pm \sqrt{\frac{r_p^2 + Z^2(2+\mu)^2 - 2 r_p Z\mu}{4}}$$

$$= \frac{r_p}{2}\left[\left(-1 + (2+\mu)\frac{Z}{r_p}\right) \pm \sqrt{1 + \left[(2+\mu)\frac{Z}{r_p}\right]^2 - 2\frac{Z\mu}{r_p}}\ \right]$$

$$c \doteq r_p\left[(2+\mu)\frac{Z}{r_p} - 1 + \frac{Z}{r_p}\right]$$

$$= (3+\mu)Z - \cancel{r_p}\, r_p \rightarrow$$ 3% high at $\mu = 20$ better for higher μ.

Consider 7F7 two in parallel.

Single	double
$\mu = 70$	70
$r_p = 44\ M$	22×10^3
$g_m = 1600$	3200×10^{-6}

$Z = 2000$

$$C = \frac{22}{2}\left[\frac{72 \times 2}{22} - 1 \pm \left(1 + \left(\frac{72 \times 2}{22}\right)^2 - 2\,\frac{2 \times 72}{22}\right)^{1/2}\right.$$

5.54
5.52
11.06

42.7   43.7   14

43.7
13.1
$(30.6)^{1/2} = 5.52$

$C = 12\cancel{2}$

To check this

$$\frac{1}{Z} = \frac{1}{12\cancel{2}} + \frac{71}{14\cancel{2}} = \frac{1}{1.96}$$ shows slight error above.

.00826   .503   .008   .511   497   008   .505

$$a \doteq (1+\mu) Z - r_p$$ (see p 13)

$$= 71 \times 2 - 22 = 120$$

---

compute $2\left(\frac{1}{22} + \frac{1}{142}\right) =$

.091
.007

Indicates sens of $\frac{.92}{4000} = 230\,\mu a/\text{volt}$

$\frac{170}{230} = .74$ volts expected full scale

7F7 Single.

$$C = \frac{44}{2}\left[\frac{144}{44} - 1 + (1 + 10.7 - \frac{2\times 70\times 2}{44}\right.$$

2.28
5.33
7.61

11.7
6.37
533

$C = \underline{167.5}$ M

Sens factor

$$K = \frac{44 + 335}{44 + 335 + 70\times 167.5} = \frac{379}{12079} = .0314$$

379
11700
12079

Sens .7 volts for full scale expected.

with

$\frac{105}{167.5} = .628$ mils plate current.

For double with

$C = 120$ current is .87 or .44 per tube

.74 obs for full scale.

KA see p (23) for computed value.

6SF5

$\mu = 100$

$r_p = 85$ M

$g_m = 1150 \times 10^{-6}$

Try approx

$C = 103 \times 2 - 85$

$$\begin{array}{r} 206 \\ 85 \\ \hline 121 \end{array}$$

give good check.

$$C = \frac{85}{2}\left(\frac{\cancel{102} \times 2}{85} - 1 + \left(1 + 5.77 - \frac{200 \times 2}{85}\right)\right)$$

2.4

$$\begin{array}{r} 1.4 \\ 1.43 \\ \hline 2.83 \end{array}$$

$$\begin{array}{r} 6.77 \\ 4.71 \\ \hline (2.06)^{1/2} = 1.43 \end{array}$$

$C = 120$ M $= a$

$\frac{105}{120} = .875$ mil plate current.

grid at $-0.\cancel{4}$ gives .875 at 90 volts.

This would indicate that unless the grid current were less in this tube the single side of 7F7 might be better.

(26) 3/13/42

6C5

$\mu = 20$

$r_p = 10M$

$g_m = 2000 \times 10^{-6}$

$$C = \frac{10}{2}\left[\frac{22\times 2}{10} - 1 + \left(1 + 19.4 - \frac{80}{10}\right)^{1/2}\right.$$

3.4

$(12.4)^{1/2} =$

3.52

6.92

$C = 34.6$

use approx form.

$C = 23 \times 2 - 10 = 36$

$\frac{105}{36} = 2.92$ mils.

can obtain this at -2.5V and 90 volts on plate.

see check on this on p 3/16/42 (V)

$$K = \frac{1}{1 + \frac{720}{82}} = \frac{1}{9.8} = .102$$

$\frac{.9}{4000} = 225\ \mu a/\text{volt}$

.75 volt full scale.

Constants using 6SF5

$\mu = 100$

$r_p = 85\ M$

$g_m = 1150 \qquad \frac{1}{g_m} = 870$ ohms.

$D = 1200$

Max current wanted for gain .17 ma.

with standby current = .403 ma.

$C = 260000$ ohms.

$= 260\ M$

$$\frac{1}{Z} = \frac{1}{260} + \frac{101}{85} = \frac{1}{260} + \frac{1}{.840}$$

$$\cancel{Z =} \quad \cancel{260 \times 8} \quad \cancel{\frac{26\ 260 \times 85}{345}} \quad \cancel{= 646}$$

$$\cancel{260} \quad \frac{260 \times .84}{260.8}$$

$Z = .835$

$$\begin{array}{r} 1200 \\ 835 \\ \hline 365 \end{array}$$

3/13/42

Summary sheet

page

13 $$Z = \frac{\cancel{I} \quad 1}{\frac{1}{c} + \frac{1}{r_p + a} + \frac{\mu}{r_p + a}}$$

$$\frac{1}{Z} = \frac{1}{c} + \frac{1 + \mu}{r_p + a}$$

$$S = -\frac{\frac{\mu}{r_p + a}}{1 + \frac{g}{Z}}$$

(15) $$= -\frac{1 - D\left(\frac{1}{c} + \frac{1}{r_p + a}\right)}{D + G}$$

$$S = \frac{1 - K}{D + G}$$

If $D = Z$

where $K = D\left(\frac{1}{c} + \frac{1}{r_p + a}\right) = Z\left(\frac{1}{c} + \frac{1}{r_p + a}\right)$

(19) $$K = \frac{r_p + a + c}{r_p + a + c(\mu + 1)} = \frac{1}{1 + \frac{c\mu}{r_p + a + c}}$$

$$\doteq \frac{r_p + a + c}{c\mu}$$

(28)

3/13/42

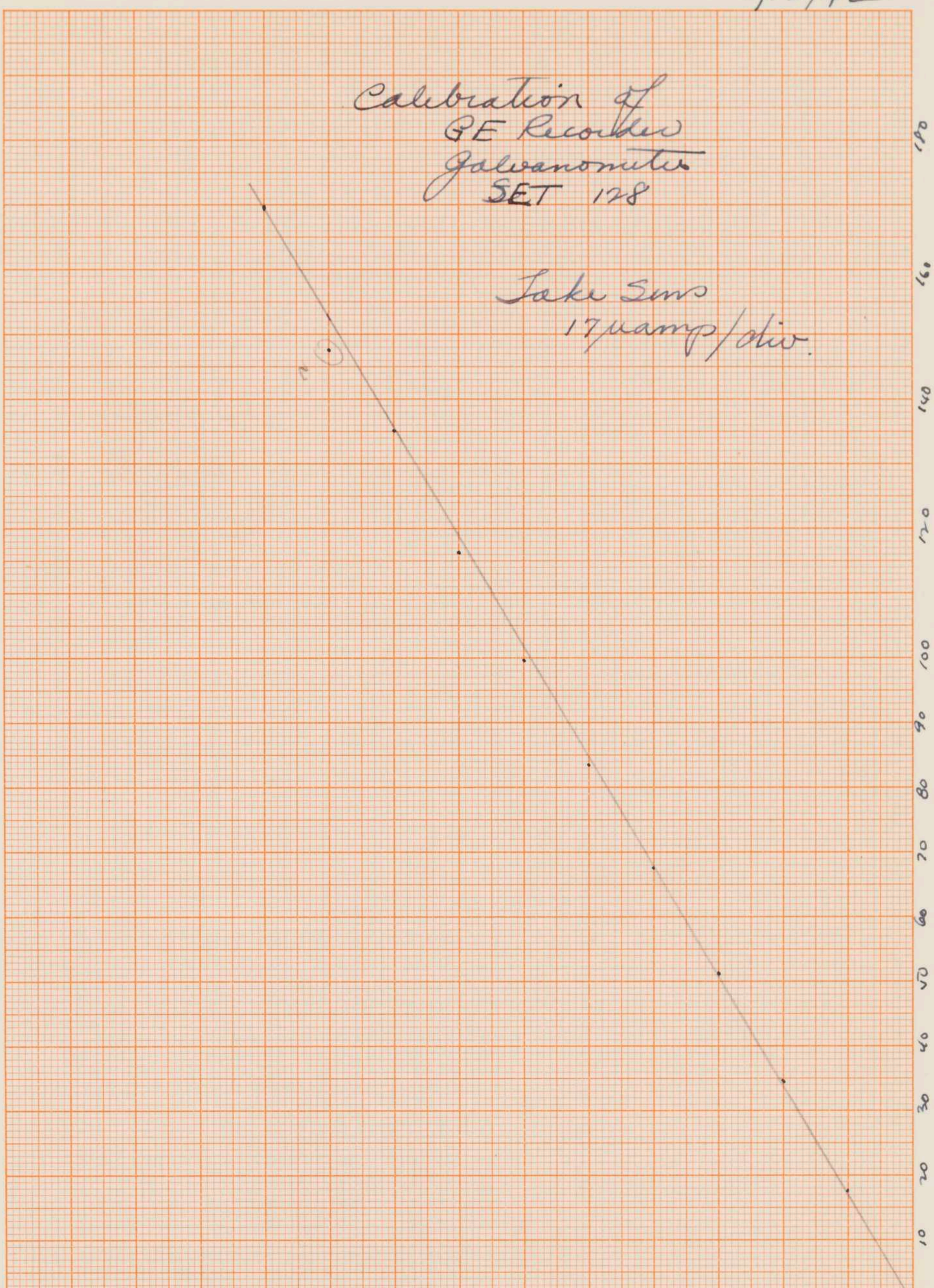
If $a = c$

$$c = \frac{r_p}{2}\left\{(2+\mu)\frac{Z}{r_p} - 1 + \left[\left((2+\mu)\frac{Z}{r_p}\right)^2 + 1 - \frac{2\mu Z}{r_p}\right]^{1/2}\right\}$$

(22) $$\doteq (3+\mu) Z - r_p$$

quite good for
$\mu > 20$
is 3% high.

3/12/42


Calibration of
GE Recorder
Galvanometer
SET 128
Take Sens
17 μamp/div.
180
160
140
120
100
90
80
70
60
50
40
30
20
10
10
8
6
4
2
0

3/13/42

6SN7 Single — Double

μ = 20 — 20

r_p = 6700 — 3350

g_m = 3000 — 6000

Take $Z_1 = 2000$

$C = 23 \times 2 - 6.7$ — $23 \times 2 - 3.35$

$C = 39.3$ — $C = 42.7$

use 39 — use 42

$$K = \frac{6.7 + 78}{6.7 + 78 + 20 \times 39} = \frac{1}{1 + \frac{20 \times 39}{6.7 + 78}} = 0.098$$

$$\doteq \frac{84.7}{20 \times 39} = .109$$

$$K \doteq \frac{87}{20 \times 42} = .103$$

90% full sens.

.15 Cal.
.82 obs

$$\begin{array}{r} 94 \\ 214 \\ \hline 308 \\ 19 \\ \hline 327 \end{array}
\qquad
\begin{array}{r} 214 \\ 19 \\ \hline 233 \end{array}$$

3/16/42

Grid current test.

6SN7	Single and double with 80M
6C5	" with 70M
7F7	" " 330M
7F7	Double " 240M

9×10^{-10} amp/cm

9×10^{-8}

1.8×10^{-7} .01

.2 μa

8×10^{-2}

$\frac{900 \times 10^{6}}{10^{2}}$

Measurement of grid Currents

3/16/42

(2)

Tube	—	V_a	R_p	E_g Volts	i_p (μa)	Gal.
7F7	Single (567)	300	328M	0	860	.0001 2
				.2	833	12
				.5	786	.001 18.3
				1.30		
				1.325	633	' ~~0~~
				1.30	638	.1 − 5.2
				1.2	656	.1 + 4.4

This shows diff in contact pot. of grid

Tube oscillates.

.005 Cond put grid to cathode.

Tube	—	V_a	R_p	E_g	i_p	Gal.
				.5	788	.001 16.8
				.8	732	.01 9.5
				1.0	695	' 14.3
				1.1	676	.1 − 9.6
			Float.	1.004	693	0
				−1.3	637	.01 −1.55
				1.5	600	.01 −1.65
				2.0	511	−1.8
				2.5	424	−1.83
				3.0	338	−1.91
				3.5	260	−1.98
				4.0	185	−2.0
				5.0	60	−2.09
				−6.0	3.5	−2.08
		other side				
		300		−6.0	80	.1 9.05
		0				
		0		−6.0	0	' 5.2
	Band of socket connected to cathode	300		−6.0	80	.1 8.5

3/16/42
(3)

		V_a	R_p		e_g	i_p	Gal.
#1	7F7 Single (234)	300	328		0	850	.0001 18.7
					.5	773	.001 11
					1.0	685	.1 4.3
					1.04	677	0
					1.5	595	.1 8
					2.0	510	8.2
					3.0	348	8.5
					4.0	209	8.5
					5.0	114	8.3
					6.0	80	8.2
#1	7F7 Double.	0	328		-6.0	0	- .1 2
		300			-6.0	82	.01 2.7
					-4.0	241	~~241~~ .01 3.2
					-3.0	393	- .01 3.1
					-2.0	498	- .01 2.9
					-1.0	750	+ .1 14.5
		300	234		-1.0	1020	+ .1 7.5
					-1.027	1014	0
					-2.0	763	- .01 2.7
					-3.0	570	-2.9
					-4.0	307	-2.95
					-5.0	150	-2.95
#2	7F7 double	300	234		-5.0	146	- 1. 2.6
					-5.0	147	- 1. 2.96
					-4.0	324	- 1. 7.33
					-3.0	538	- .1 1.38
					-2.0	781	- .1 2.12
					-1.8	830	- .1 2.10
					-1.45	922	- 1. 0.85
					-1.6	881	- .1 1.67
				NOTE + →	+1.4	1300	+ .00001 37.1
					-1.45	906	- .1 1.37
					-1.4	926	+ 1. 1.0

3/16/42

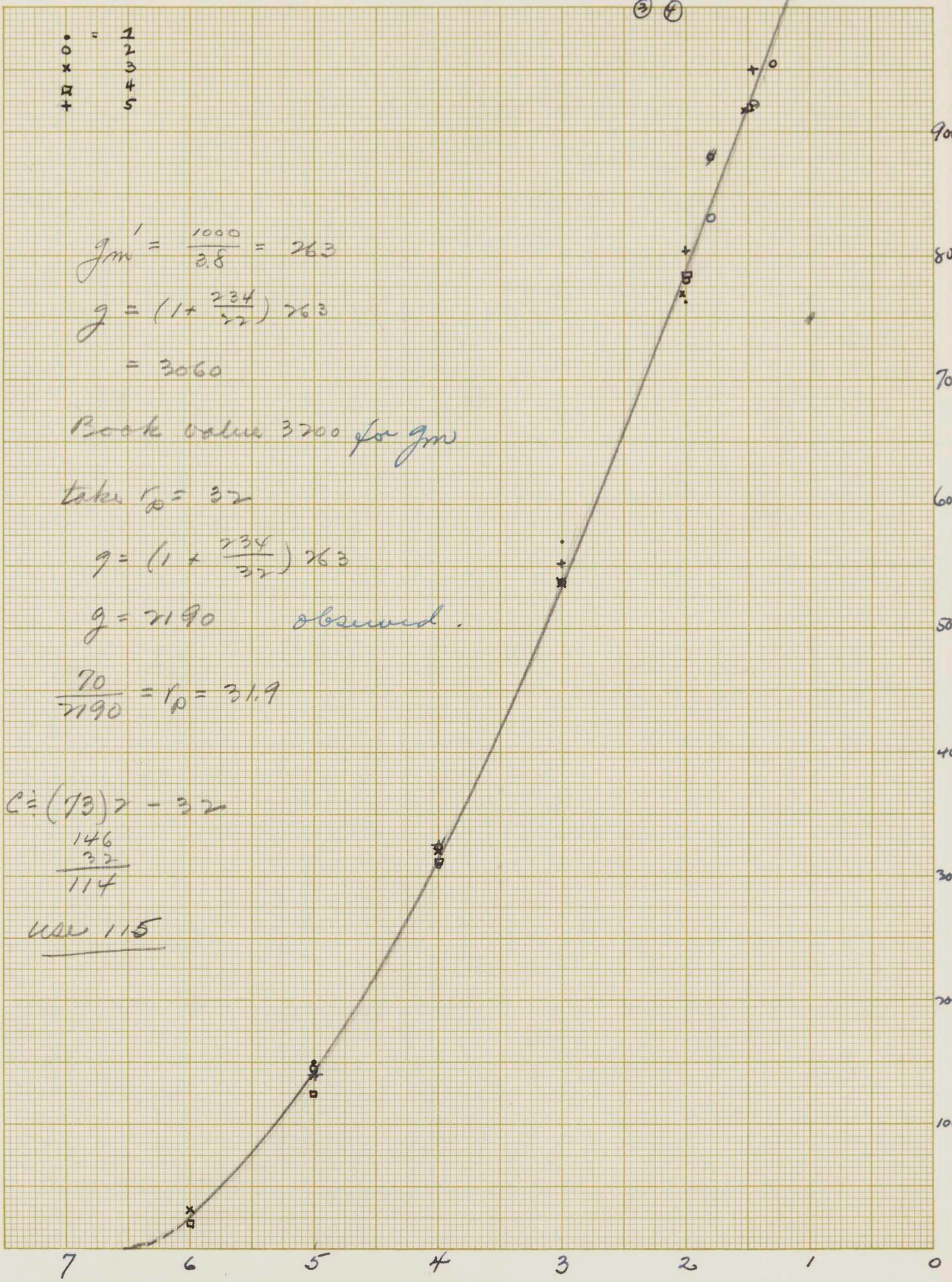
(4)

			V_a	R_1	e_g	i_p	gal.	
#2	7F7	double	300	234M	-1.3	954.	.1 + 4.55	
					-1.0	1034.	.01 + 12.0	
					-.5	1168.	.0001 + 9.2	
					0	1263	.00001 + 5.	
#3	7F7	double	300	234	0	1276	.00001 + 7.0	
					-1.528	917	1. + .5	? should this be !
					-2.065	768	.1 - 12.2	max. neg grid current
					-3.0	538	1. - 7.10	
					-4.0	320	1. - 3.67	
					-5.0	140	1. - 1.62	
					-6.0	32	1. - 0.62	
#4	7F7	double	300	234	-6.0	20.	1. - .58	
					-5.0	124.	1. - 3.0	
					-4.0	312.	1. - 3.5	
					-3.0	463.	.1 - 1.07	
					-2.0	785	.1 - 1.83	max. neg. grid current
					-1.488	920	1. 0	
					-1.0	1050	.001 + 1.72	
					-0.5	1185	.0001 + 12.4	
					0	1277	.00001 + 6.4	
#5	7F7	double	300	234	-1.478	950	1. + 3.0	
					-2.0	806	.1 - 2.6	
					-3.0	552	.1 - 1.63	
					-4.0	325	1. - 8.0	
					-5.0	140	1. - 3.3	

Some mistake

3/16/42

③ ④



$g_m' = \frac{1000}{3.8} = 263$

$g = (1 + \frac{234}{22})\, 263$

$= 3060$

Book value 3200 for g_m

take $r_p = 32$

$g = (1 + \frac{234}{32})\, 263$

$g = 2190$ observed.

$\frac{70}{2190} = r_p = 31.9$

$C \doteq (73)2 - 32$

$$\begin{array}{r} 146 \\ 32 \\ \hline 114 \end{array}$$

use 115

		V_a	R_1		e_g	i_p µa	galv.	
#1	6C5							
		300	~~~70M~~	pot	−1.266	3472.	~0	
			66.5M	"	−2.43	3166.	1/ −6.7	max neg. grid current
			1.0	"	−4.0	2762.	1/ −3.63	
			67.5M	"	−6.0	2260.	1/ −2.73	
				"	−8.0	1784	1/ −2.05	
				"	−9.82	1373	1/ −1.57	
				Simpson meter	−18.	73	1/ −0.43	
				"	−15.	386	−0.67	
				"	−12	900	−1.10	
				"	−9.8	1360	−1.35	
#2	6C5		70.5M	meter	−10.	1455	1/ −3.4	
				"	−12	1066	−2.67	
				"	−15	618	−1.75	
				"	−18	280	−1.2	
				"	−8	1823	−3.6	
				"	−6			
				pot.	−6.06	2230	−3.63	
				"	−4.0	2690	−3.55	
				"	−2.0	3155	−3.35	
				"	−1.462	3287	.1 ~0	
				"	−1	3400	+ 32.	
#1	6SN7 single 45B		80.6M	pot	−1.0	3150	.1 + 4.2	
				"	−1.437	3050.	1. 0	
				"	−2.0	2920.	1. − .7	
				"	−4.0	2476	1. − 1.07	10^{-8}
				meter	−6.0	2050	1. − 1.9	
				"	−8.0	1660	1. − 2.1	
				"	−10.0	1300.	1. − 2.1	
				"	−12.0	926.	1. − 1.93	
				"	−15.0	445	1. − 1.35	
				"	−18.0	120	− .72	

			V_a	R_1		e_g	i_p μa	galv.
#1	6SN7	double	300	80.6	meter	-18.	138.	1. - 1.57
					"	-15.	507.	1. - 2.03
					"	-12.	1040.	1. - 2.4
					"	-10.	1395.	1. - 2.45
					"	-8.0	1775.	1. - 2.3
					"	-6.0	2175.	1. - 1.93
					"	-4.0	2610.	1. -1.05
					pot.	-2.0	3066.	1. -.67
					"	-1.495	3190.	0
					"	-1.0	3313.	.1 + 8.0
#2	6SN7	double	300	80.6	pot.	-1.0	3337	.1 + 6.4
					"	-1.386	3241	1 0
					"	-2.0	3090	1. - 1.45
					meter	-4.0	2625	1. - 1.43
					"	-6.0	2175	1. - 1.93
					"	-8.0	1780	1. - 2.05
					"	-12.	1045	1. - 1.90
					"	-15.	567	1. - 1.63
					"	-18.	210	1. - 1.13

7/18/42

(7)

6SN7 double. ← G.E. Recorder pen

V_{meter}	V	D
.1	.125	1.6
.2	.25	3.1
.3	.375	4.7
.4	.5	6.3
.5	.625	7.85
.6	.75	9.35
.65	.812	10.0

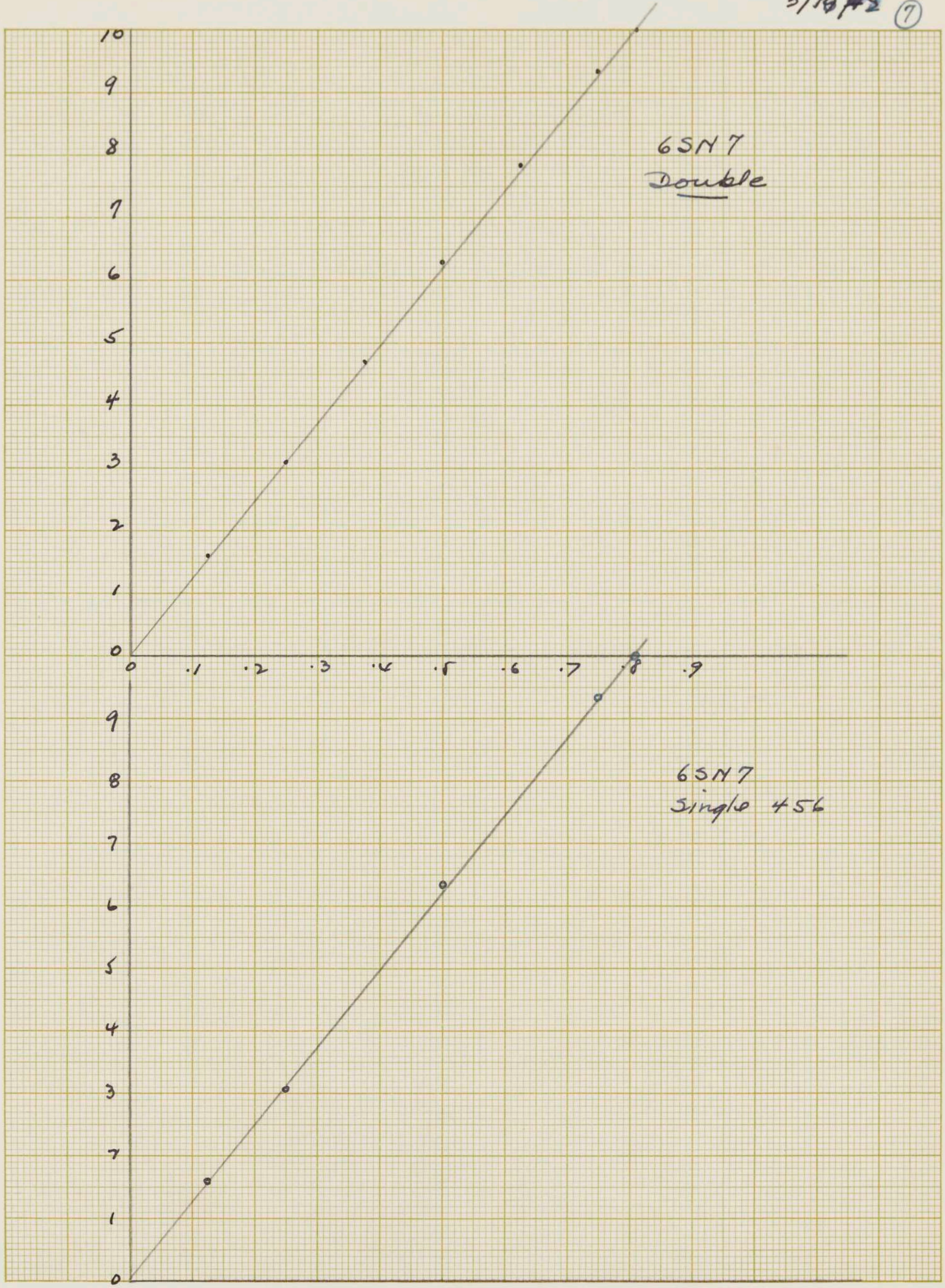
Read on Simpson micro ammeter scale with 10,000 ohm series ext. Must correct for internal res. — 12,500 total

Single 4-5-6

.125	1.6
.25	3.08
.5	6.35-
.75	9.25
.81	10.0

Bias is 2.6 volts

3/18 #2 7



Gal res measured some time ago was $\underline{2130}^{\omega}$ 3/17/42 ①

$R_{CO} = 2000$ instead of 5000 given in book. Exp shows that $R_{CO} = 1250$ really gives a still better "overall" action

Compute values for

2000 : 2000 shunt   See 3/11/42 ④

$$A = G\,\frac{k - \frac{D}{G}}{k+1} \qquad C = G\,\frac{k - \frac{G}{D}}{k+1}$$

$$B = G\,\frac{k\left(1 + \frac{D}{G}\right)}{k^2 - 1} \quad \text{or} \quad \frac{A + D}{k-1}$$

Special case of $D = G$

$$A = G\,\frac{k-1}{k+1} \qquad B = G\,\frac{2k}{k^2-1} = \frac{2G}{k - \frac{1}{k}}$$

	k	k	k^2	$k+1$	$k-1$	$\frac{k-1}{k+1}$	A	k^2-1
	1	k						
db 50	$\sqrt{10}$	3.162	10	4.162	2.162	.52		9 ~~99~~
100	10	10	100	11	9	.818		99
150	$\sqrt{1000}$	31.62	1000	32.62	30.62	.938		999
200	100	100	10,000	101	99	.98		9999

$\frac{D}{G} = \frac{1200}{2000} = \frac{1200}{2000} = .6$

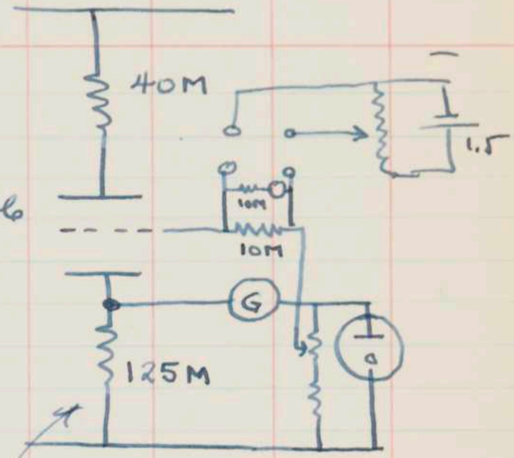
		$k-.6$		A	C	$k-1.67$	B
4.162		2.562	.615	1230	430	1.49	1173
11		9.4	.855	1710	910	8.33	324
32.62		31.02	.951	1902	1102	29.95	111
101.		99.4	.986	1970	1170	98.33	32
∞				2000	1200		0

3/17/42

(2)

μa	V.	G.E.
1.07	.127	2.2
200	.25	4.4
300	.375	6.55
400	.50	8.70
470	.587	10.00

Double 7F7



$i_0 = 840\,\mu a$.

Operation of gal indicates $Z = 1250$

assume $g_m = 2200$

$$r_p = \frac{70}{2.2} = 31.8M.$$

$$Z^{-1} = \frac{1}{125} + \frac{71}{71.8}$$

$$= .08 + .975 = 1.055 \quad \therefore Z = 950 \text{ ohms}$$

$$.8 = .08 + \frac{71}{r_p + 40}$$

$$r_p + 40 = \frac{71}{.72} = 98.5$$

$$r_p = 58.5$$

This indicates an inconsistance here.

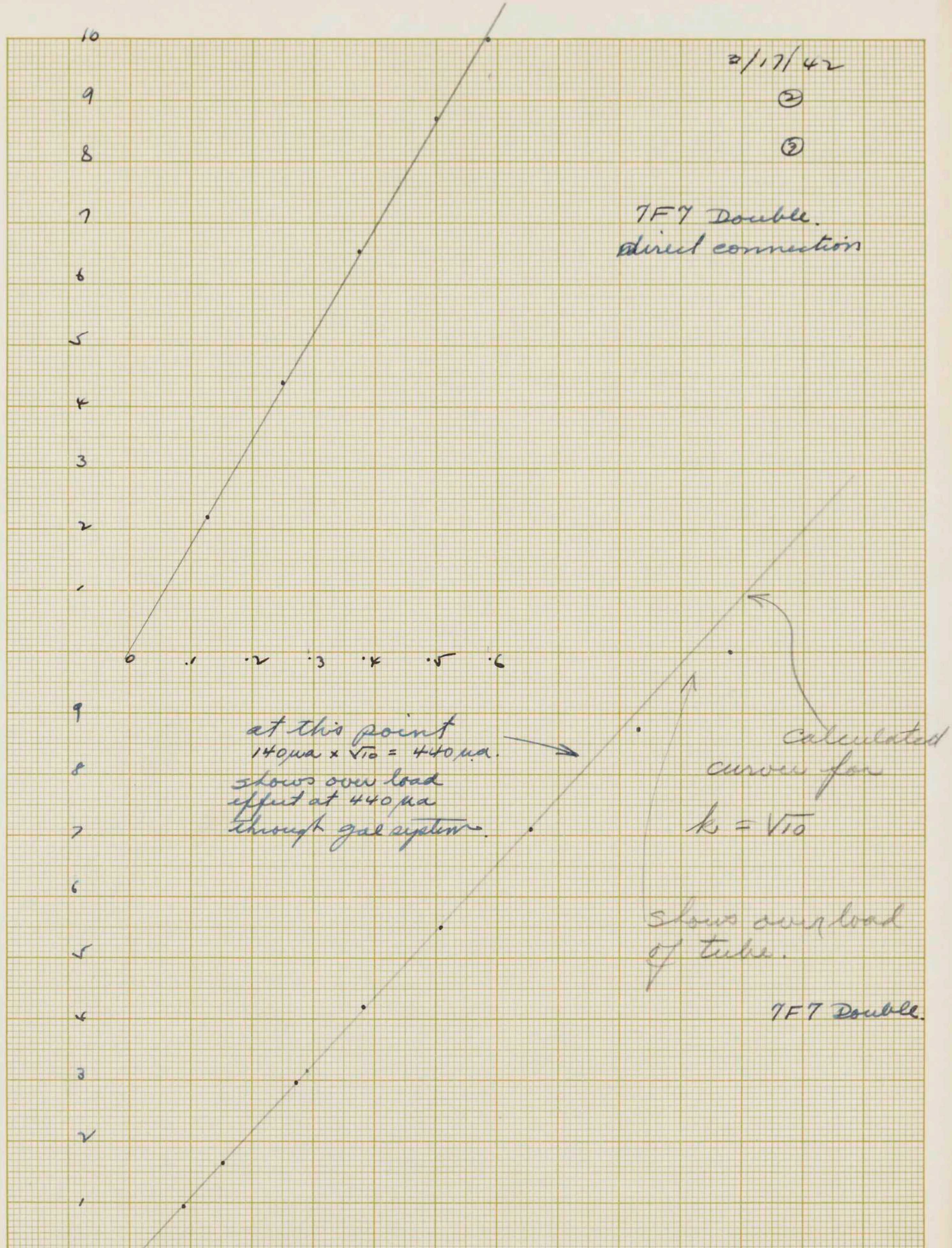
3/17/42
3

Response with $\sqrt{10}$ pad.

See 3/17/41 1

V	G.E.
1.029	5.6
.175	.95
.309	1.65
.546	2.95
.765	4.2
1.016	5.55
1.310	7.10
1.663	8.75
1.961	10.00

$$\left.\begin{array}{l} A = 1230 \\ C = 430 \\ B = 1123 \end{array}\right\} \text{7F 7 Double}$$


2/17/42
②
③
7F7 Double.
direct connection
at this point
140μa × √10 = 440μa.
shows over load
effect at 440μa
through gal system.
Calculated
curve for
k = √10
shows overload
of tube.
7F7 Double.
10
9
8
7
6
5
4
3
2
1
0
.1
.2
.3
.4
.5
.6
0
.2
.4
.6
.8
1.0
1.2
1.4
1.6
1.8
2.0

3/17/42

4

Double.
$g_m = 5720$
$r_p = 3.5$
$\mu = 20$

Consider case with

$C = 20$

then $i_p = 5.25$ mils.

obtain 6 mils at 70 volts - 2. for double.

$$\begin{array}{r} 300 \\ 175 \\ \hline 125 \end{array} \qquad \frac{125}{5.25} = 24\,M$$

$$\frac{1}{Z} = \frac{1}{20} + \frac{21}{\cancel{31}\,27.5} = .05 + \overset{.763}{\cancel{.678}} = .813$$

$$= .728$$

$Z = \overset{1.225}{\cancel{1.37}}\ M$ this is higher than wanted.

Try ~~$C = 16$~~ $\qquad C = 20 \quad a = 25$

~~$i_p = 6.57$~~

~~take ~~70~~ 70 volt drop.~~

~~$a = \frac{125}{6.57} = 19\,M$~~

~~$Z = .0625 + \frac{21}{26}$~~

3/17/42
(5)

Reconsider case of 6SN7 Double.

$\mu = 20$
$r_p = 3.5$
$g_m = 5720$

with a tube drop of 195 volts a current of 30 mils would be possible

$c = 3500$
$a = 0$

$$Z^{-1} = \frac{1}{3.5} + \frac{21}{3.5} = \frac{22}{3.5}$$

$$Z = \frac{3.5}{22} = .159 \quad \text{or} \quad 159 \text{ ohms}$$

with $D = 1250$ $d = 1100$

Max possible current would be

$$\frac{105}{3500 + 1100 + 2000} = 16 \text{ mils.}$$

Max expected for good linearity about 8 to 10

By using an "L" pad instead of a T max current would be $\frac{105}{4000} \doteq .25$ mils.

this shows that an "L" pad might increase range about 20 %.

With Highest sens. of 0.17 ma

$.17 \times \sqrt{1000} = 5.4$ ma.

Case with 15 ma max, possible would be quite good.

$15 \times 2000 = 20$ Volts

$\frac{85}{15} = 5.6 = \max\ c + d$

or $\frac{\cancel{55}\ 5}{} = \max\ c$

$i_{co} = \frac{105}{5} = 21$ mils.

to get 21 mils at grid voltage of -2
tube drop would be 140 volts

$105 + 140 = 245$

$\frac{55}{21} = 2.6$ M as a good value for "a"

Take $a = 2.5$ M
$c = 5$ M

$\frac{1}{z} = \frac{1}{5} + \frac{21}{6} = .2 + 3.5 = 3.7$

$z = \cancel{1.82}\ 270^{\omega}$

$\therefore\ d = 1000^{\omega}$ would be good.

$2000 + 1000 + 5000 = 8000$

$\frac{105}{8} = 13.1$ max possible mils

$\frac{13.1}{5.4} = 2.4$ which should be
a good enough ratio for
linear response.

3/17/42
①

a = 25M   6SN7 Double.
c = 20 M

V	G
.50V	8.0
.25	4.0
.636	10.0

as good as the gal.

$\frac{105}{20+2}$ = 5 mils ∴ 2.5 mils about max

100 Lu pad.

A = 1710   B 324   C 910

V		Bias
.636	1.0	−1.44
1.803	2.8	
2.5	3.96	
~~5.0~~		
3.75	6.0	
5.0	7.96	
6.25	9.75	
6.48	10.0	

This is too low since floating potential

1.94
1.44
─ 3.38
(This seems to be a little high but checks

Bias for bal.   Grid res
− 2.93 volts   0
− 2.98   "   11 meg
.05

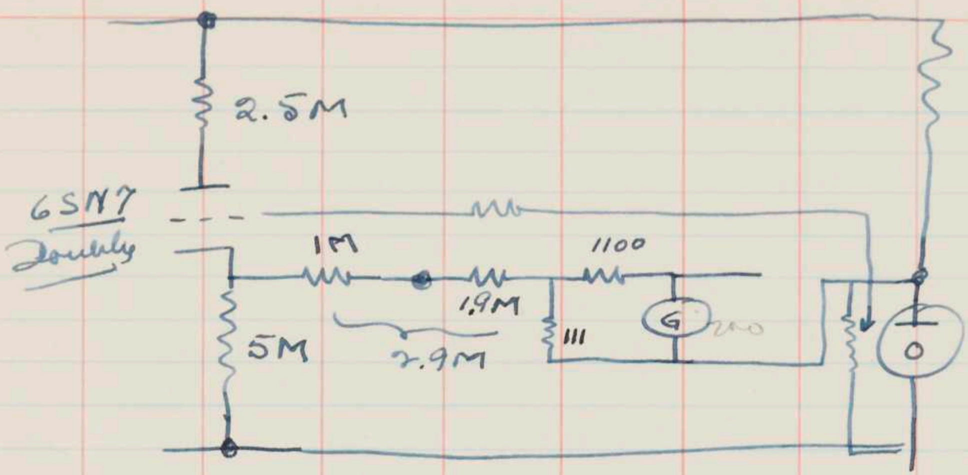
$\frac{.05}{10^7} \doteq 5 \times 10^{-9}$ as grid current

a = 20 M		Grid res	Bias
c = 20 M			
6.055	10	0	2.893
6.033	10	11	2.92
			.027

20 - 20 condition more satisfactory

3/17/42

(8)



150 Lw reduction in gain.

10 scale	V	G.E.	Bias	Float	Grid res.		grid i
				5.735			
3.75	3.85	1.92					
7.0 6.7	7.077	3.61	2.53	3.035	0		
9.7	10.15	5.32	2.671		11	.14	1.2×10^{8}
meter 12.4	12.92	6.82					
15.5	16.098	8.5					
18.3		10.0					

3/17/42

9

Calculation of gain control network for D = 1200 and G = 2000

$\frac{D}{G} = .625$

	db	k	$(k-1)$	$k+1$	$k-.6$	(α) $\frac{k-.6}{k+1}$	Δ A	A 2000(α)	C (A − 800)	B A + 1200		B B/k−1
3	0	1	0	—	—	—		0	0			∞
4	20	1.585	.585	2.585	.985	.381	762	762	(0) −38	1962		3355
5	40	2.511	1.511	3.511	1.911	.544	326	1088	288	2288		1513
—	50	~~3.98~~ 3.162	2.162	4.162	2.562	.616	144	1232	432	2432		1125
6	60	3.981	2.981	4.981	3.381	.679	126	1358	558	2558		858
7	80	6.31	5.31	7.31	5.71	.781	204	1562	762	2762	500	520
8	100	10.0	9.0	11.0	9.4	.855	148	1710	910	2910		323.4
9	120	15.85	14.85	16.85	15.25	.905	100	1810	1010	3010	250	202.7
10	140	25.11	24.11	26.11	24.51	.939	68	1878	1078	3078		127.6
11	∞						122	2000	1200	3200		0

GE. Rec.

3/17/48

8

Sens <u>.525 div</u>/volt

$k = 31.6$ $\therefore$ $31.6 \times .525 = 16.6$ Div/volt

or .602 volt full scale

This checks very well with expected value.

Linearity as perfect as can be read.

Current max is $.17 \times \sqrt{1000} = 5.4$ ma.

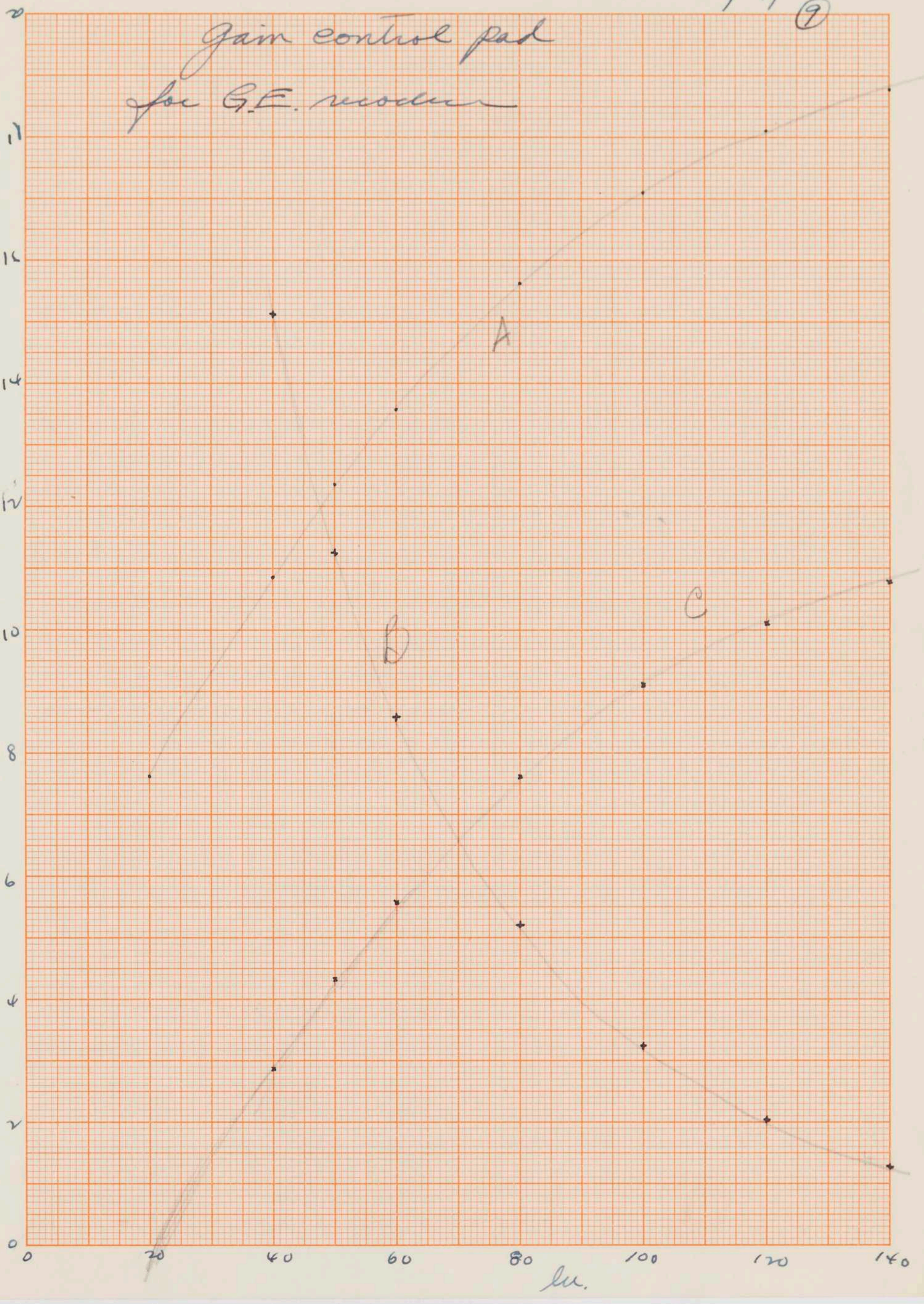
Circuit gives $\therefore \frac{5.4}{18.9} = .284$ ma/volt

with current in 20 meg cct 5×10^{-8} give one volt

$\therefore$ gain could be $\frac{2.8 \times 10^{-4}}{5 \times 10^{-8}} = 5300$ in current.

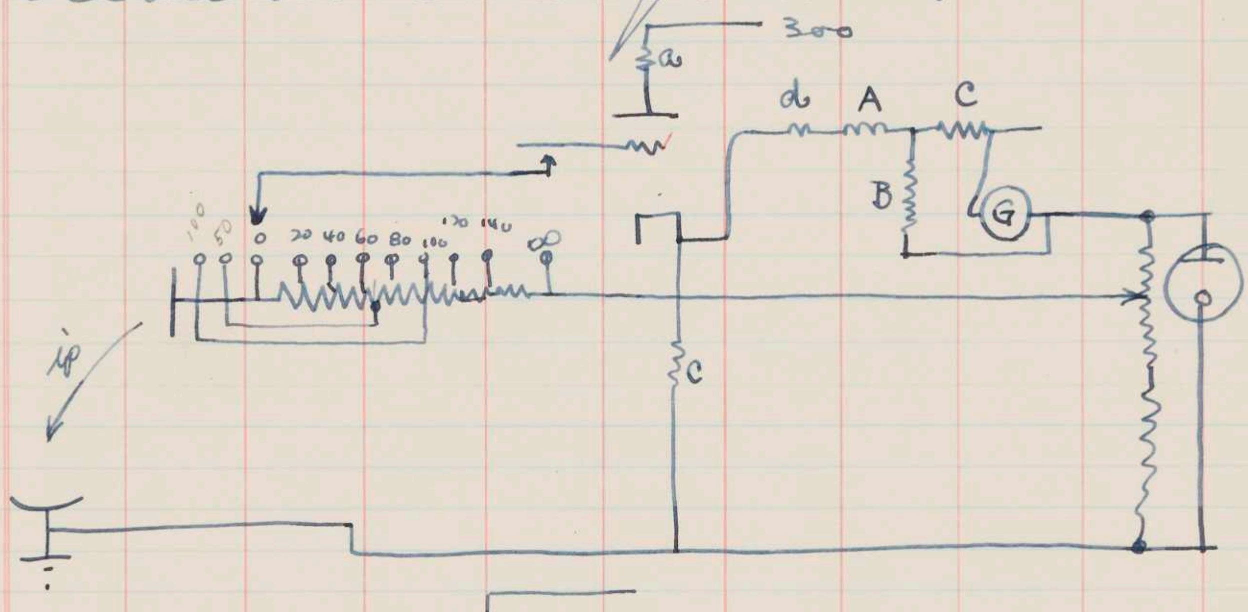
3/17/42 9

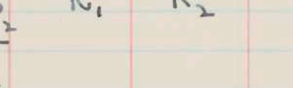
Gain control pad for G.E. recorder



Gain control for galvanometer worked out and constructed. Objection ~~the~~ to this method of control is that very little protection is offered to the galvanometer if the cct is designed to give good linear response for the ~~top~~ low gain step on gal control.

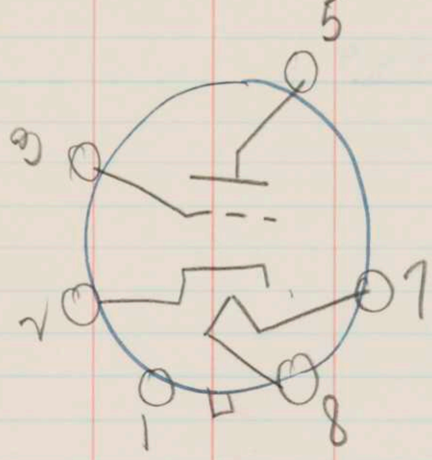
A better way of controlling would be as follows

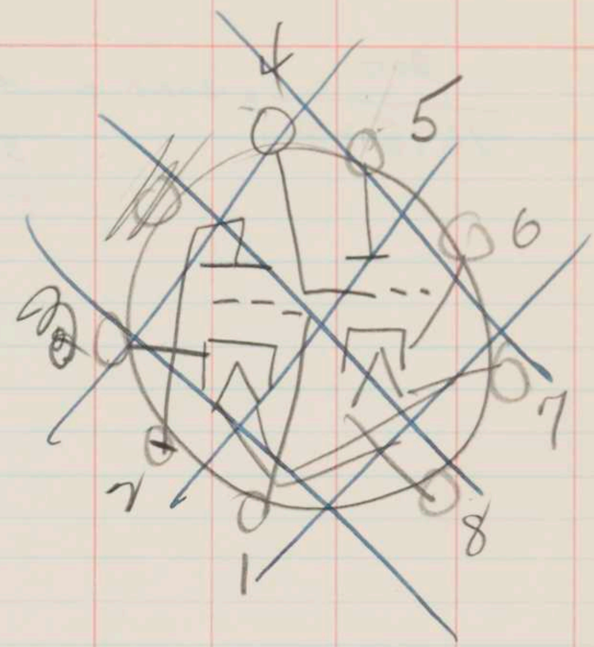




$$k = \frac{R_1 + R_2}{R_2} \qquad R_2 = \frac{(R_1 + R_2)}{k}$$

6SF5

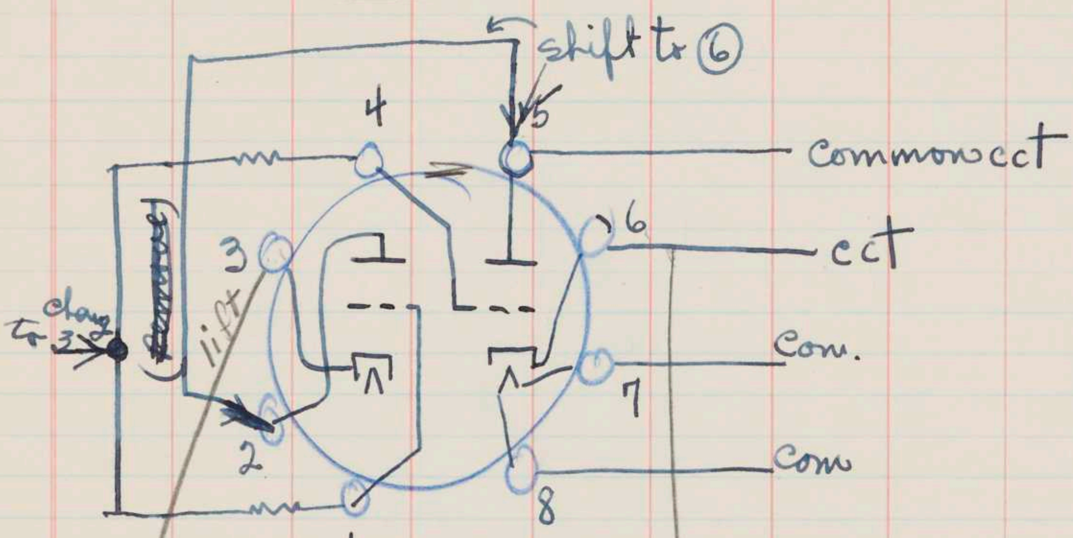




$\mu = 100$

$r_p = 85M$

$g_m = 1150$



Two changes would allow 6SF5 and 6SN7 to be used.

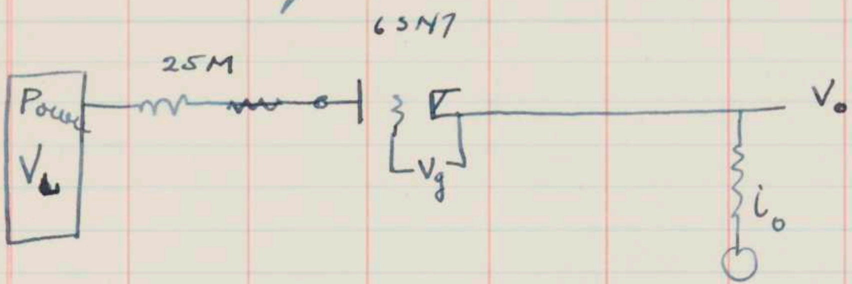
$$\frac{200}{1675+200} \times 4000 = \left.\begin{matrix}426\\533\end{matrix}\right\} \underline{\text{range}}$$

$1.4 \times \underline{400M}$ 560

3/20/42

①

Tests to determine variation in 6SN7 grid voltage needed to correct for line variation



V_L	V_o	V_g	i_o
4600	4000	-11.2	0
4500	4000	0	2.2

3/21/42

Some tests on H. V. regulator ①

Line V_L	Drop 811	grid 811	Plate on grid Current	i_1	i_{Load}	V_{Load}	
1000	850	-15		0	0	0	Ampifier tubes out of cct.
"	750	-10		60^{-6}	0	100	
	320	-5		270	0	430	
	100	0	30^{-6}	390	0	700	
2000	1800	-23	0	0	0	0	
"	1750	-22	0	10	0	—	
	1720	-20	0	35	0	70	
	1450	-15	0	190	0	300	
	1000	-10	0	410	0	700	
	480	-5	0	680	0	1200	
	200	0	31	810	0	1450	
	250	0	31	770	750	1380	
3000	2430	-23	0	160	200	260	
	2400	"	0	200	0	300	
	2130	-20	0	340	0	550	
	1680	-15	0	570	0	1000	
	1150	-10	0	840	0	1500	
	580	-5	0	1130	0	2000	
	680	-5	0	1060	1000	1900	
	280	-0	31	1290	0	2300	
	360	-0	31	1210	1200	2200	
4000	2650	-23.	0	550	0	1000	
	2330	-20	0	710	0	1250	
	1800	-15	0	990	0	1750	
	1250	-10	0	1250	0	2300	
	950	-7.5	0	1350	0	2500	
	650	-5	0	1340	0	2850	
	500	-4	0	1340	0	3000	
	620	-4	0	1340	1500	2800	Shows over compensation
	310	0	31	1330	0	3200	without load of other
	430	0	31	1335	1600	2950	tubes.

3/21/42

②

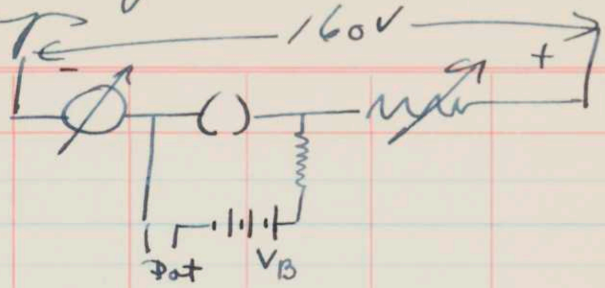
V_b	Drop 811	grid V 811	grid dept current	i_c	i_{Load}	V_{Load}
5000	2800	-23	0	990	0	1750
	2480	-20	0	1150	0	2100
	2000	-16	0	1350	0	2500
	1880	15	0	1340	0	2650
	1290	-10	0	1330	0	3220
	1400	-10	0	1330	1600	3000
	1200	-8.2	0	1325	1750	3200
	660	-5	0	1310	0	3850
	530	-4	1	1295	0	3950
	500	-3.5	1.5	1295	0	4000
4850	620	-3.5	"	"	2050	3730
	490	0	30	"	2150	3850
6000	2930	-23	0	1340	0	2500
	2540	-20	0	1330	0	2900
	1920	-15	0	1310	0	3500
	1400	-10.5	0	1290	0	4000
	1550	-10.5	0	1295	2050	3750
	1750	-8.3	0	1290	2200	4000
	680	-5.0	0	1260	0	4650
	400	0	30	1270	0	5000

3/22/47

①

Measurement of drop over neon lamp

Masda
NE $\frac{1}{4}$ Watt 105-125V
Ext R 30,000
105
on base

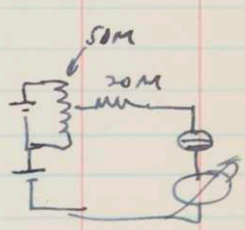


V_B	Pot	Sum.	i.	
55.0	7.65	62.65	200^{-6}	
	7.75	62.75	240	
	7.8	62.8	300	
	7.7	62.7	350	
	7.62	62.6	390	
	6.7	61.7	630	
	6.4	61.4	700	
	5.81	60.8	800	
	5.26	60.26	900	
	4.73	59.7	1000	
	3.60	58.6	1200	
11:00 AM	2.55	57.55	1500	
	1.72	56.72	2000	
	2.00	57.0	3000	
	1.47	56.47	2500	
	1.05	56.05	1550	Min here.
	1.2	56.2	1360	Meter 1
			1320	" 2

shows that some "aging" has taken place to lower drop.

11:10

5.84	60.8	71.0	
6.41	61.4	100	
			changed circuit
6.16	61.16	70	
6.20	61.2	70	
6.68	61.68	100	
7.23	62.23	150	
7.30	62.3	200	
		52	goes out.
6.07	61.07	58	



5300 — 105 — 125
53

~~6000~~ — ~~1~~15
6000

$$1800 + 2\times10^{-3} R_{24} = 120\times10^{-3} R_K$$

$$\left.\begin{aligned} 120 R_K - 2 R_{24} &= 1800 \\ 3.2 R_K + 22 R_{24} &= 8200 \end{aligned}\right\}$$

2.4
24
264

36
38

$$264 R_K - 4.4 R_{24} = \cancel{19800}$$

3960

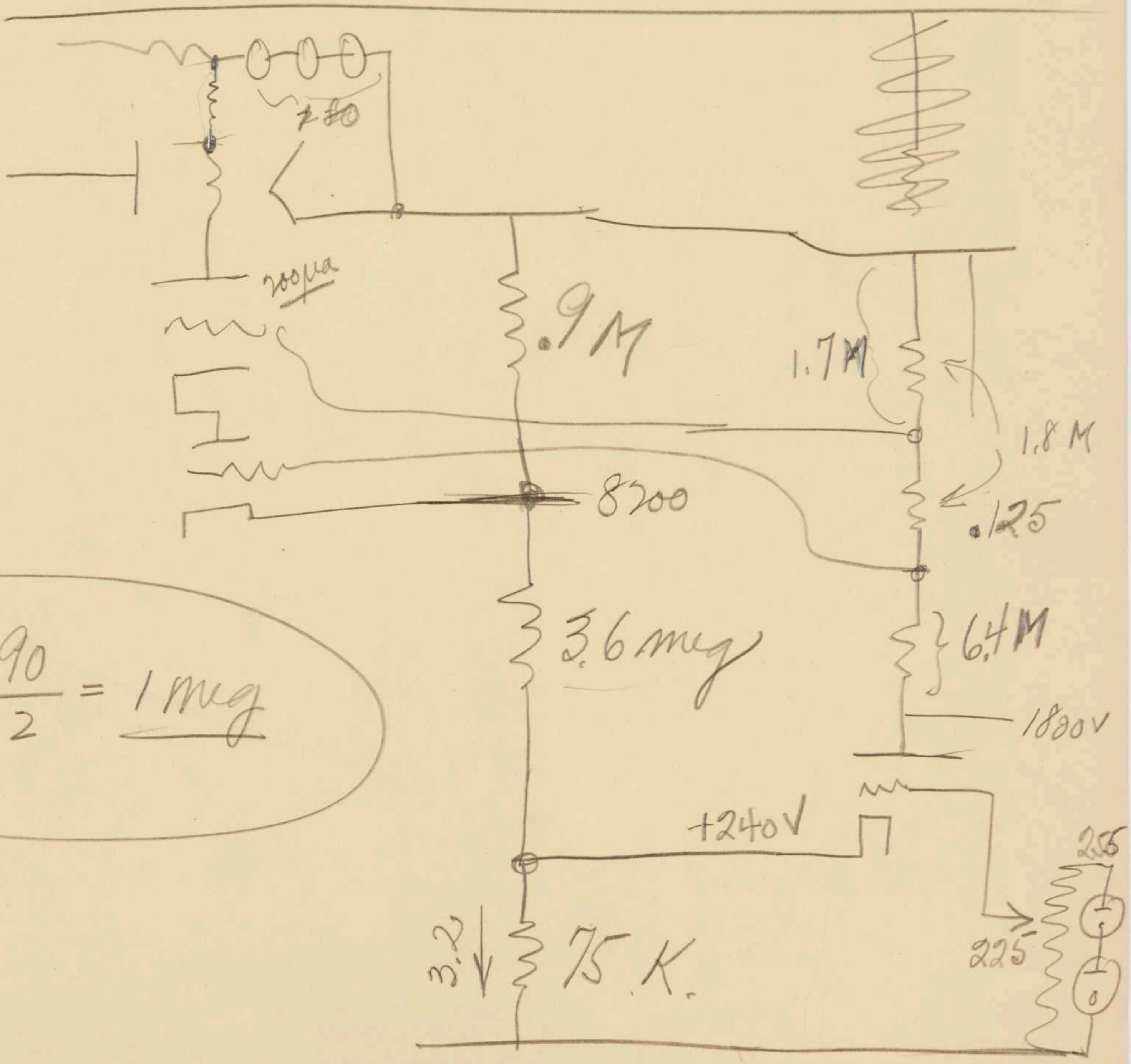
$$6.4 R_K + 44 = 16400$$

$$270.4 R_K = 20360$$

$$R_K = 75.1\,K$$

$$R_4 = 900\,K$$

$$\frac{9000 - 1800}{2} = \frac{7200}{2} = 3.6 \text{ Meg}$$



$$\frac{190}{.2} = 1 \text{ meg}$$

~~Take~~ Take $T_1 = 1000$ V
grid bias about -8V. $\}$ 811

$\boxed{\text{Take } T_2 = 1800 \text{ V.}}$

$\boxed{\text{Take } T_3 = 1800 \text{ V}}$ — Bias -15 V
Current 1 mil

$\frac{R_4}{R_K} \doteq \cancel{6}60$

Max output 10 K.

$2 \times 10^{-3} R_4 + 2.2 \times 10^{-3} R_{24} + 3.2 \times 10^{-3} R_K = 10 K.$

$(R_4 + R_{24}) = 60 R_K$

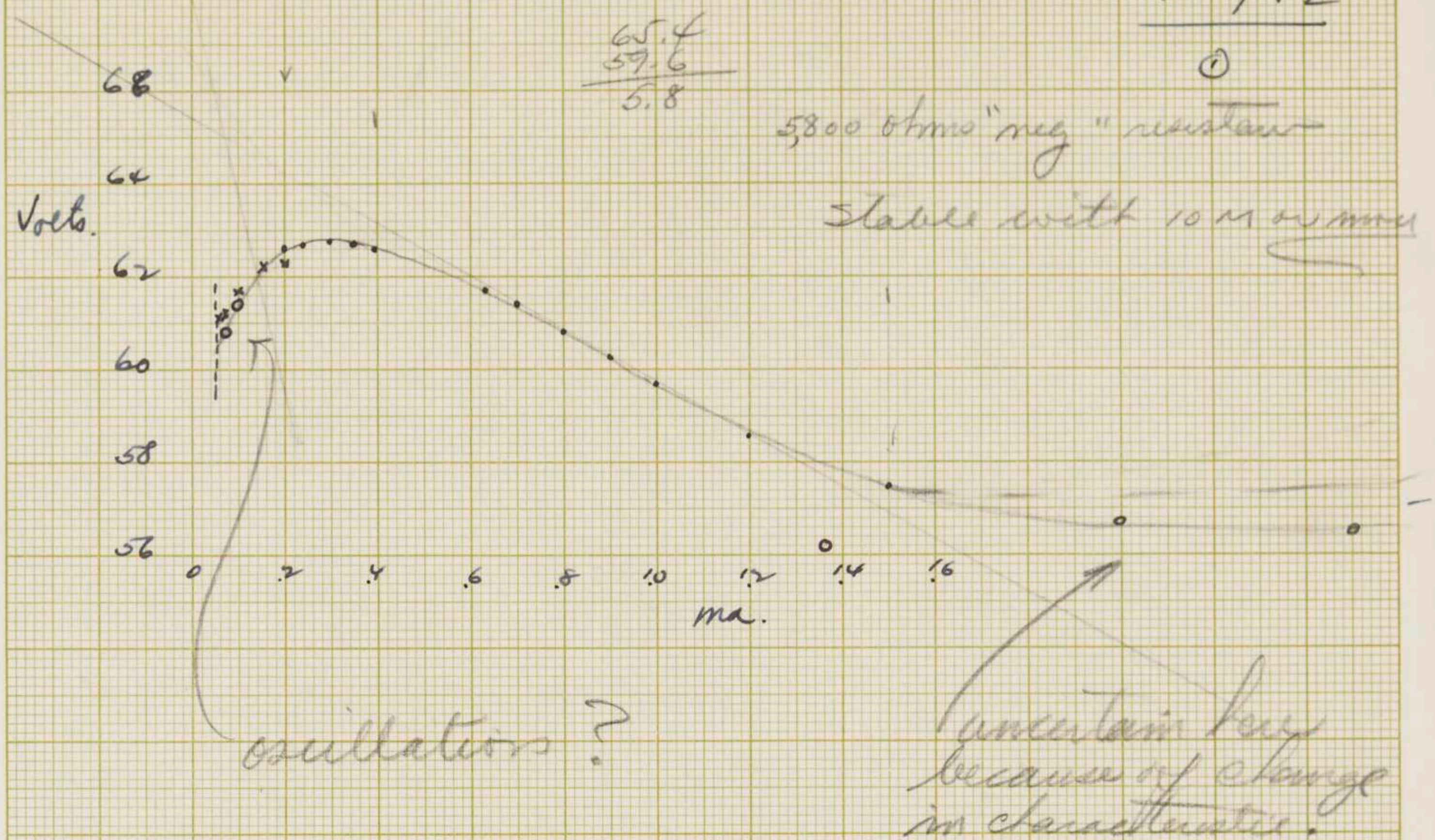
~~18~~

$2 \times 10^{-3} R_4 = 1800$

~~1800~~ $R_4 = \underline{900 K}$

3/22/42

①



500

$\frac{300}{.4} = 750,$

$1.5 \times 750 = 1.2$

1500 is about max v

6800

Operation of voltage reg for 2000 – 7000 V supply

3/23/42

①

Discussion for 4000 V output. $= V_0$

Input is 4000 V + $V_1 = V_L$

No load condition:–

i_2 will be largest it is to be.

Set cathode bias of T_3 to over compensate.

A decrease in V_0 will increase i_3, this cut down i_2 and $\therefore V_1$ which compensates for change.

Put grid of T_3 at 105 V then with $V_1 = 500$ adj compensator until i_2 starts to control T_1

$V_1 = 600$ $V_0 = 4000$ $V_L = 4600$

i_1

i_2 .19

i_3 1.48

i_4 1.8

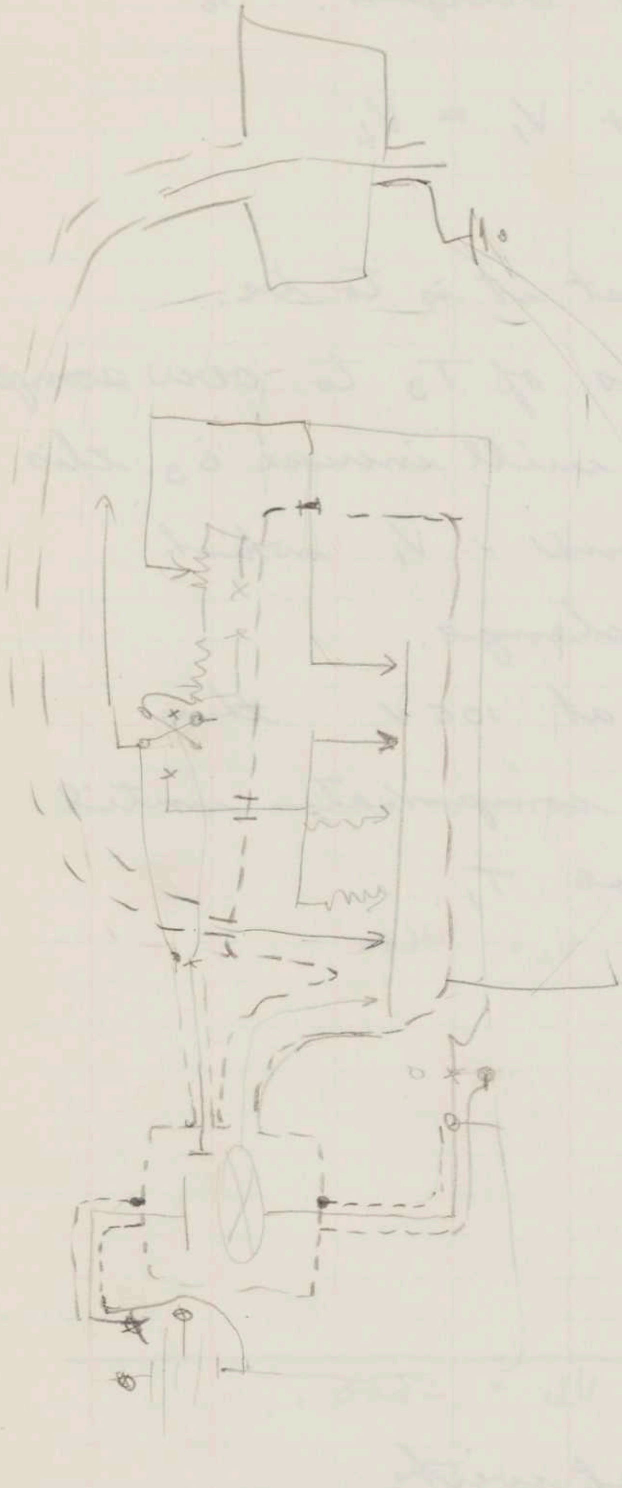
$i_4 + i_2$ 2.0

$i_3 + i_2 + i_4$ 3.48 $= i_1$

$V_1 = 1600$ $V_0 = 4000$ $V_L = 5600$.

Exp shows that with

$\sqrt{2}$ / 000



Readings on constant current
Part of ckt (amp-tube out)

3/23/42
(2)

V_0	V_{T_3}	(i_3) i_{T_3}
2000	200	.350
	400	.300
	950	.200
	1500	.100
3000	200	.510
	400	.480
	950	.380
	1200	.~~34~~0
	1400	.300
	1930	.20

$V_3 \doteq V_0 - i_3 R_3$

Since i_3 may be made nearly constant at any value

$V_3 + (i_3 R_3)_{const} = V_0$

To get variable V_0 make V_3 change.

Consider 300 μa as normal min current i_3 with $1.55 \times 10^6 \times 300 \times 10^{-6} = \underline{465} = V_{20}$

$67 \times 10^3 \times .3 \times 10^{-3} = \underline{20.1} = V_{2a}$

Possibly 2 megs would be better if .3 is used.

Total drop 485 V.

~ 1.6
$\underline{.061}$

$8 \times 50 = 400\,K. \parallel 200\,K$ $\frac{8}{6} = 1.3$

14.
15.3
.6
1.6 Lower end of res.

$\frac{400}{2000} = .2$

with $\frac{485}{.2} = 2420 = V_0$ grid = cathode.

7/7/42 (3)

V_L	i_4	i_3	i_2	V_3	V_0	R	i_0
~4000	.95	.3	.2	950	2600	.4	0
"	"	"	.19	"	"	"	6
3400	"	"	.14	890	25~~4~~0	."	10
4000	"	"	.19	9500	2600	.4	10

~~R_{3a}~~ i_3

$(R_{3a} + R_{3b}) i_3 - i_4 (R_4) = $ grid bias

i_3 independent of V_0

~~i_4~~ $i_4 R_4 + (i_2 + i_4) R_{24} = V_0$

$$i_4 (R_4 + R_{24}) = V_0 - i_2 (R_{24})$$

$$i_4 R_4 = \{V_0 - i_2 (R_{24})\} \frac{R_4}{R_4 + R_{24}}$$

$$\text{grid bias} = (R_{3a} + R_{3b}) i_3 - \left[\frac{V_0 \times R_4}{(R_4 + R_{24})} \right] + i_2 \frac{R_{24} R_4}{R_4 + R_{24}}$$

R_{3a} changed to 200M from 67M.

3600	.85	.38	.18	480	2600	.4	0
4000	.85	.38	.19	480	2600	.4	0
3400	.85	.38	.145	440	2500	.4	10
3600	.85	.38	.1.8	480	2600	.4	10
~6400	1.35	.6	.22	680	4000	.4	0
6000	"	"	.205	650	4000	.4	9.4
8200	1.7	.75	.23	800	5000	.4	0
7300	"	"	.21	780	"	"	10.5

$T = .2$

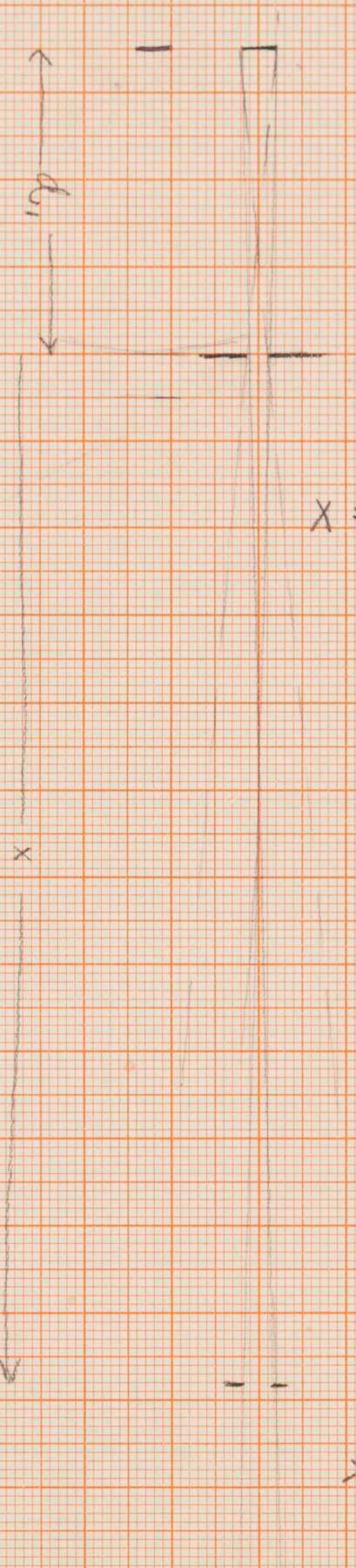
$A_1 = .1$

$d_1 = 1.75$

$X = 6"$

$$\frac{6(.3)}{1.75} + .1 = A_2$$

$$\frac{1.8}{1.75}$$



$$X = d\,\frac{\left(\frac{A_2}{A_1} - 1\right)}{\left(\frac{T}{A_1} + 1\right)} = d\,\frac{(A_2 - A_1)}{(T + A_1)}$$

3/23/42
④

V_b	i_4	i_3	i_2	V_3	V_0	R	C_0
~~3400~~ 3900	.65	.28	.2	400	2000	.4	0
2900	"	"	.165	360	"	"	6.6

3/24/42

It seems impossible to get good regulation at any voltage ~~with~~ and at the same time have wide range in control.

This indicates that a step control and a fine control between steps will be needed.

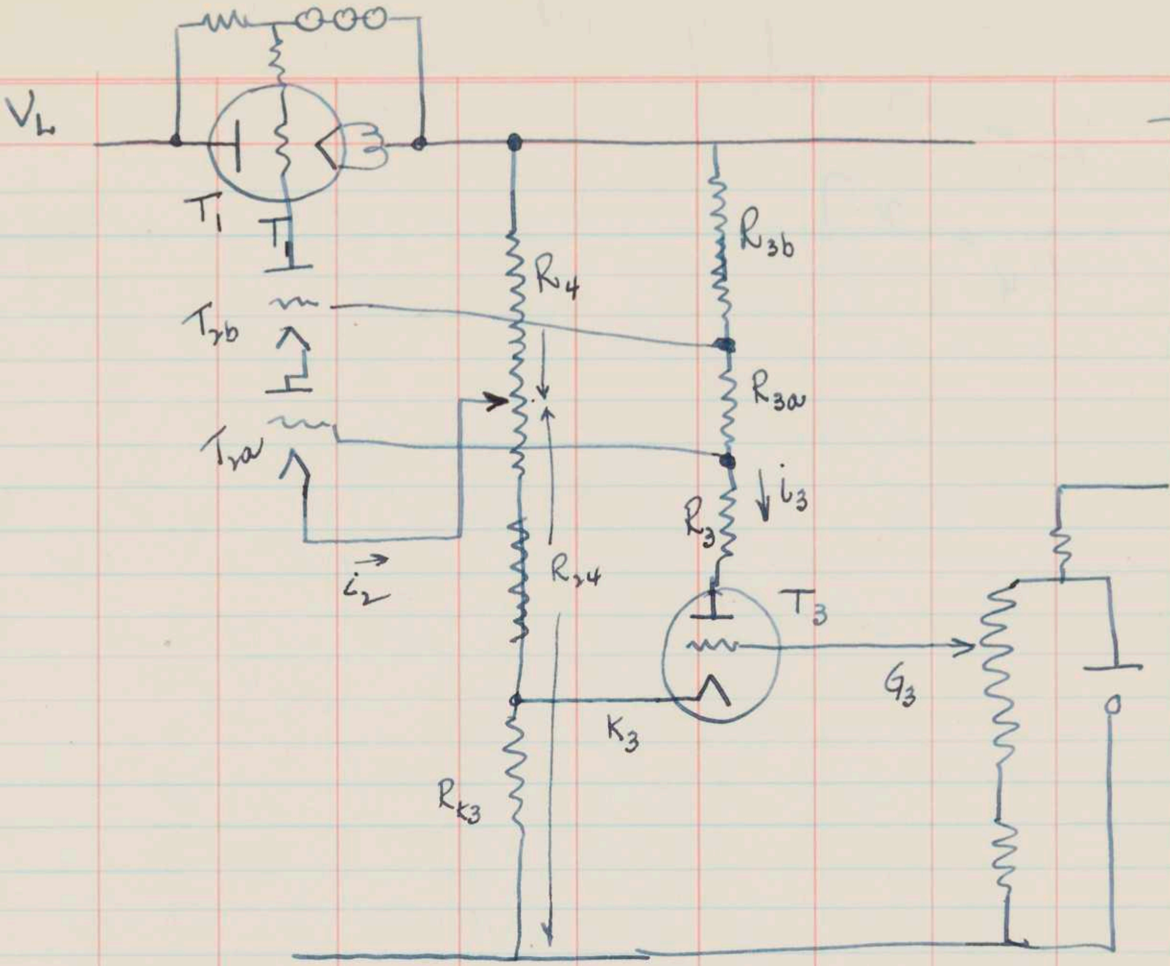
Take 11 steps.

1	1500	9	5500
2	2000	10	6000
3	2500	11	6500
4	3000		
5	3500		
6	4000		
7	4500		
8	5000		

And then have a fine control of 0 to 600 volts for over-lap.

3/24/42

①



Tube drops are
T_1
T_{2a}
T_{2b}
T_3

$$\frac{R_{24} + R_4}{R_{k3}} \doteq 70 \text{ or } \cancel{\text{more}} \text{ less.}$$

at present R_{3b} = 1.55 meg. } = 1.65 meg
R_{3a} = .10 "

With 1 mil $= i_3$, drop over T_{2a} could be ~1650

Present value of R_3 = 3.2 megs.

with 1 mil. V = 3200 + 1650 = 4850

This would put 1150 across T_3 at 6000
and 2150 " " " 7000

This shows that 1.3 max might be possible

giving 2140 across T_2 which is carrying small current

$i_3 = 1.2$ at 7000 V

$i_4 = 2.7$

3/24/42
2

Present $R_4 + R_{24} =$

$\underbrace{11M + 50M}_{R_{K3}} + 1{,}600\,M \ \ + \underset{\uparrow}{200} \ \ + 400 + 100 \ \ = 2361$

$\frac{2361}{61} = 39$ this is less than 70

$\frac{7000}{2361} = 2.96$ mils max

if 2140 is to be voltage $T_2 = T_{2a} + T_{2b}$

$R_4 \doteq \underline{700\,M}$

~~Of R_4~~

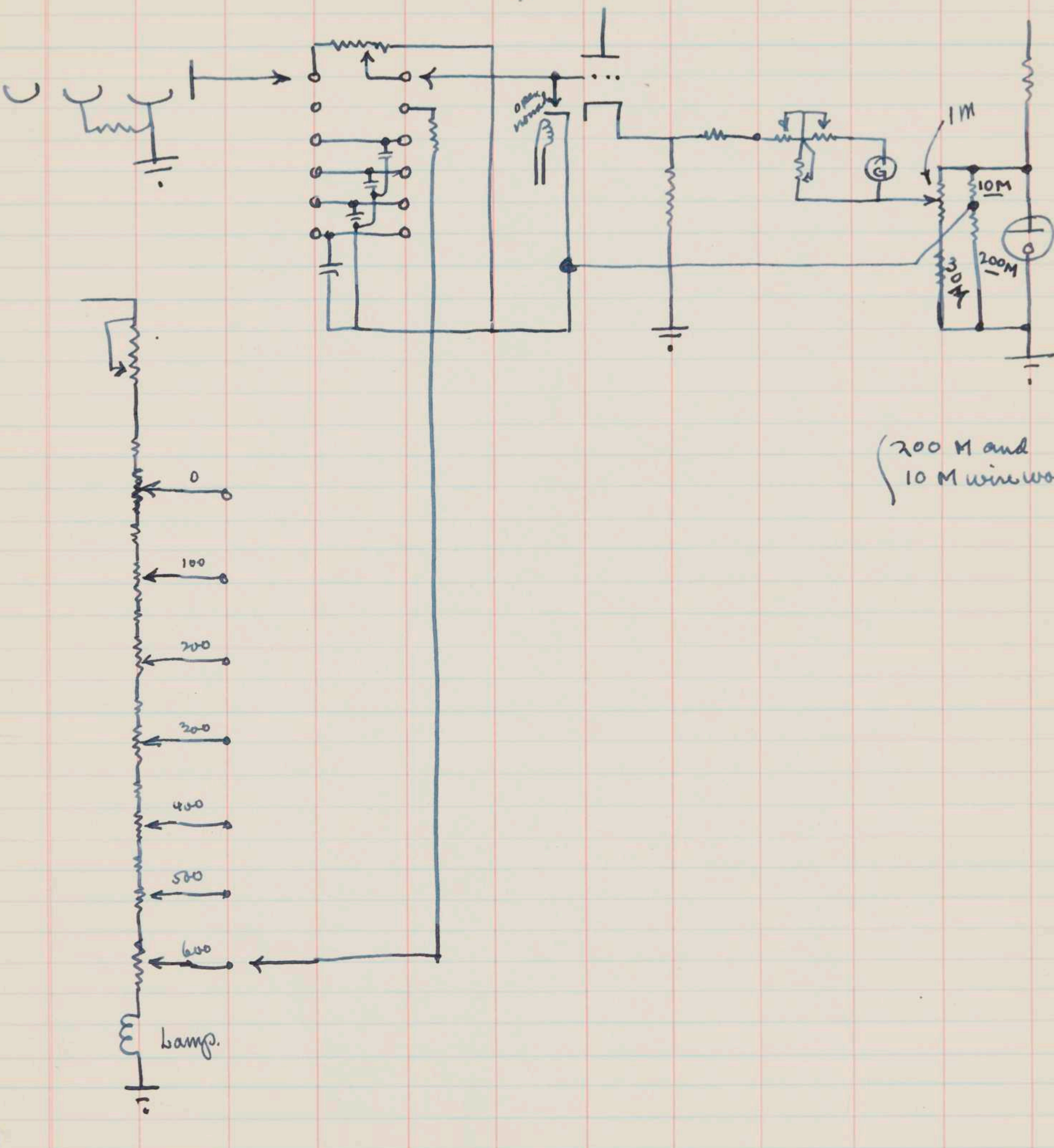
Try using 700 M for $V_0 = 1500$
(Reg not so very good)

Try 700 for 4000 V.

640 M work very well over whole range.

3/28/42
(1)

Remarks on adjustment of internal lamp. for checking 931



(200 M and 10 M wire wound.)

4/10/42

Studies of the internal lamp cct - ①

External lamps (L+N) filter 20 set 24 cm. filament to mult center.
Balanced to 61 mils on "el. eye."

Mult set to give exact 10 on GE Rec. scale.

	Rot Mult Volt	Meter	Gain Internal		ExR.	Def	
8:10	692.7	700					
	"	"					
	"	"	5	Full	20,600	10	
	968		5	-100	"	10	
	975		5	-100	20,600	10	Slight decrease with time
	975	975	6	0	21,870	10	
	697		5	0		10	
	698		5	0		10	
	"		Std	0		10	
	697		5	0		10	
			4	-100	16,040	10	
	693.3		Std	0		10	
	"		5	0	20630	10	
	"		4	-100	16,000	10	
	"						
	502		4	0	16000	10	
			3	-100	11550		
	363.5		3	0	11,550	10	
	"		2	-100	7,930		

Mult	Int			
264.5	2	0	7930	10
"	1	-100	4709	10

970	5	-100	20500	10
966	Std	-100	—	10
967.6	Std	-100		
	5	-100	20490	10
	6	0	21680	10
192	1	0	4716	10

All of above show quite good checks.

With this voltage response is linear as shown by use of 22% transmission ~~neutral~~ tint filter. Check within accuracy of reading.

685	Std	0		
"	5	0	20680	10

Check of Neutral tint filter using Std lamps was exact.

4/10/42

3

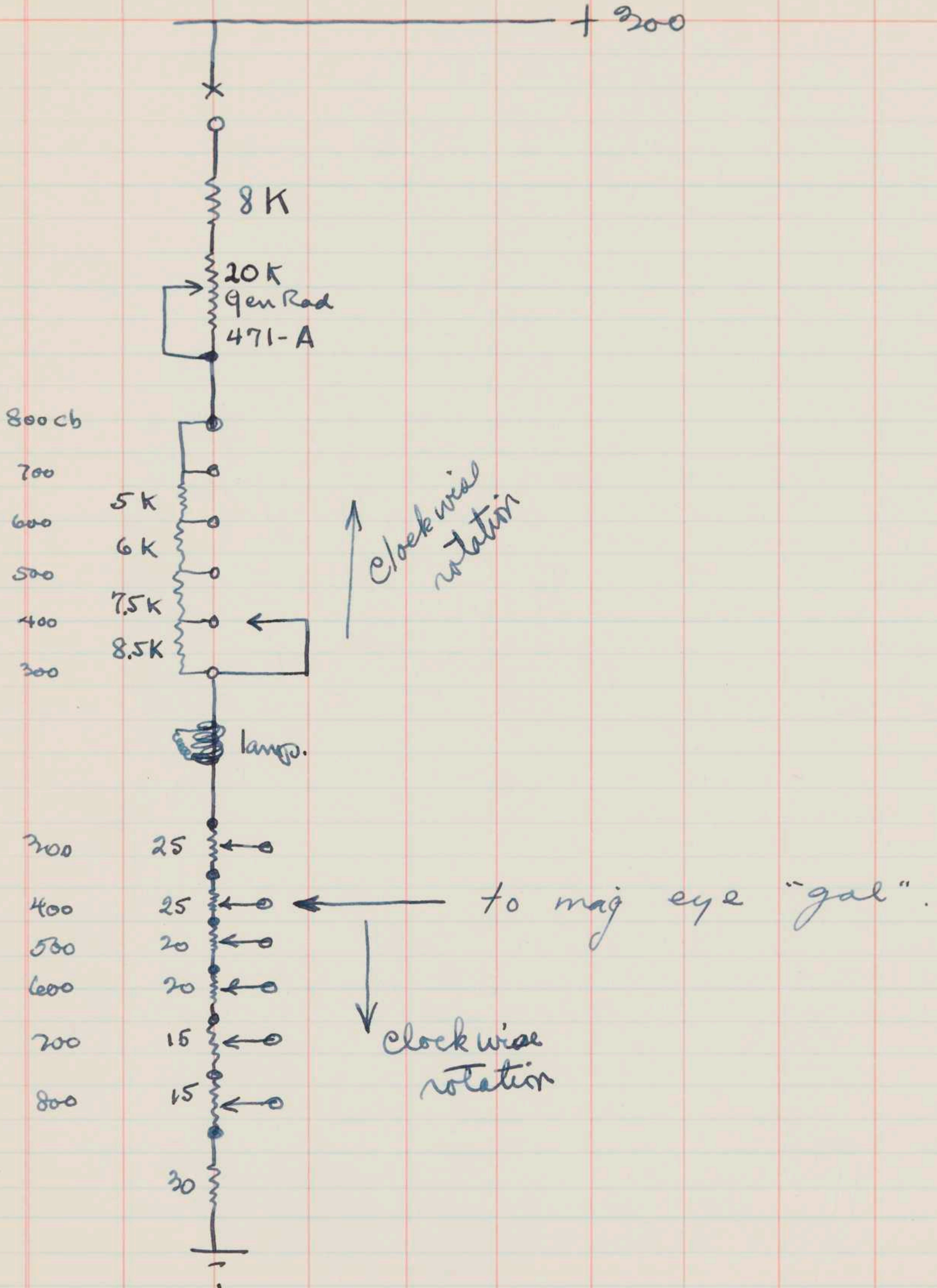
Summary of prestam needed.

	Outside	On switches and fixed	Total	
1	4710	4155	8865	
				4,595
2	7930	5530	13460	
				5,455
3	11,550	7365	18,915	
				6,418
4	16,000	9.333	25,333	
				7,398
5	20,600	12,131	32,731	
				8,670
6	21,870	19,531	41,401	

Use at upper end Variable 8000

					Total fixed
		865 (add)			
1	→ add			8865	8000
			0		
2		5460		13460	8000
			5000		
3		5915		18915	13000
			6000		
4		6333	~~6000~~	25333	19000
			7500		
5		6,231		32731	26500
			8500		
6		6,401		41,400	35,000

Wanted


+300
8 K
20 K
Gen Rad
471-A
800 cb
700
5 K
600
6 K
500
7.5 K
400
8.5 K
300
Clockwise rotation
lamp.
300
25
400
25
500
20
600
20
700
15
800
15
30
to mag eye "gal".
Clockwise rotation

4-11-42
MBM
ASW

Standardization of Test Equip. Light Scale
Lining up Trimmer Potentiometers

Time	Int. Lamp Sel. Position	$V_{mult.}$ for 100 div.	Mult. Sens.	
5:06	5	687.9	full	← {adj. trimmer pot #5 {std. against external std. lamp.
				← open shutter to check room light. none observable - all light from ext. std was exactly read therefore
:08	5	962.1	-100 cb.	
				← enter Moore
5:21	5	962.6	-100 cb.	
	6	"	full	correct for leakage. ← adj. trim pot. #6
:24	5	688.6	"	
	4	"	-100 cb.	
				← adjust trimmer pot #4
	4	496.6	full	← correct for leakage
	3	"	-100 cb	" " "
				← adjust trimmer pot. #3
5:37	3	361.3	full	
	2	"	-100 cb.	
				← adj. trimmer pot #2
	2	263.1	full	
5:41	1	"	-100 cb.	← lamp current almost exact -190
				← adj. trimmer pot #1
5:43	5	686.5	full	good check

Some remarks on radiation measurements.

Take "zero level" as P_0 watts effective ~~falling on~~ for generation of indication In our case photo cathode current

With yellow spectral dist

the sens is 500 watts per ampere.

∴ Zero level of amperes is

$\frac{P_0}{500} = i_{K0}$ zero level of cathode current.

Let a_r = effective area of receiver.

$_R W_0 = \frac{P_0}{a_r}$ = watts per sq. cm at surface of receiver for zero level.

Conversion factor for lumens per watt

is in our case 500 lumens per watt

Let $C_{L/W}$ = conversion factor

$C_{L/W} P_0 = L_0$ = zero level of luminous flux

$$\frac{L_0}{a_r} = {}_{cm^2}L_0 = \text{zero level of lumens per sq. cm.}$$

$$C_{L/W}\, W_0 = {}_{cm^2}L_0$$

$$= \frac{C_{L/W}\, P_0}{a_r} = \frac{L_0}{a_r}$$

In our case

$C_{\frac{L}{W}} = 500$ lu/watt

$P_0 = 5 \times 10^{-14}$ watt

$a_r = .46$ cm^2

"Zero level" of watts per cm^2 = 1.08×10^{-13}

or

"Zero level" of lumens/cm^2 = 5.4×10^{-11} lumens/cm^2

a summary of some of
of Moore's results 4/12/42

③

$$\bar{J}(\lambda) = 1.177 \times 10^{16} (m\mu)^{-5} \; 10^{-\frac{3040}{m\mu}}$$

(Normal) watts per $m\mu$ per unit solid angle from 1 cm^2 source at 2047°K.

$$\log_{10} \bar{J}(\lambda) = \underbrace{16.0708 - 5 \log_{10} (m\mu)^{-5}}_{} - \frac{3040}{m\mu}$$

see table on 4/8/42 B

At 560 $m\mu$ This function modified by the P_1 (yellow filter) and the $CuSO_4$ (21979) 20 g/100 ml filter has a max of <u>37.4 × 10^{-5} watts</u> per $m\mu$ per unit sol. ang. from a 1 cm^2 source (at 2047°K.) (page 31) is $\bar{E}(\lambda)$

The normalised curve was integrated as 7040 squares of (.005 units high) × 2 $m\mu$ wide

This gives <u>70.4 μ m</u>. for "integrated normalised source"

Note that this power is not uniformly effective in producing photoelectric current.

$\overline{E(\lambda)}$ when modified by the relative response curve of the 931 tube has a normalized max at 550 and an "area" of 48.5 μ m.

$\bar{E}_\lambda$ modified by 931 = ?

Take R.C.R. Sc. through P, and find normalized area. $= A_0$

Do same when modified by 931 $= A_{931}$

Ratio $\frac{A_0}{A_{931}}$ gives .931 "distortion"

$48.5\mu m \times \frac{A_0}{A_{931}}$ = effective area for substitute source.

The ~~modified~~ mult has a certain spectral sensitivity ~~would~~ which could be written as

$R_D(\lambda)$ which in our case is in amp. per watt. per $m\mu$ range in wave length.

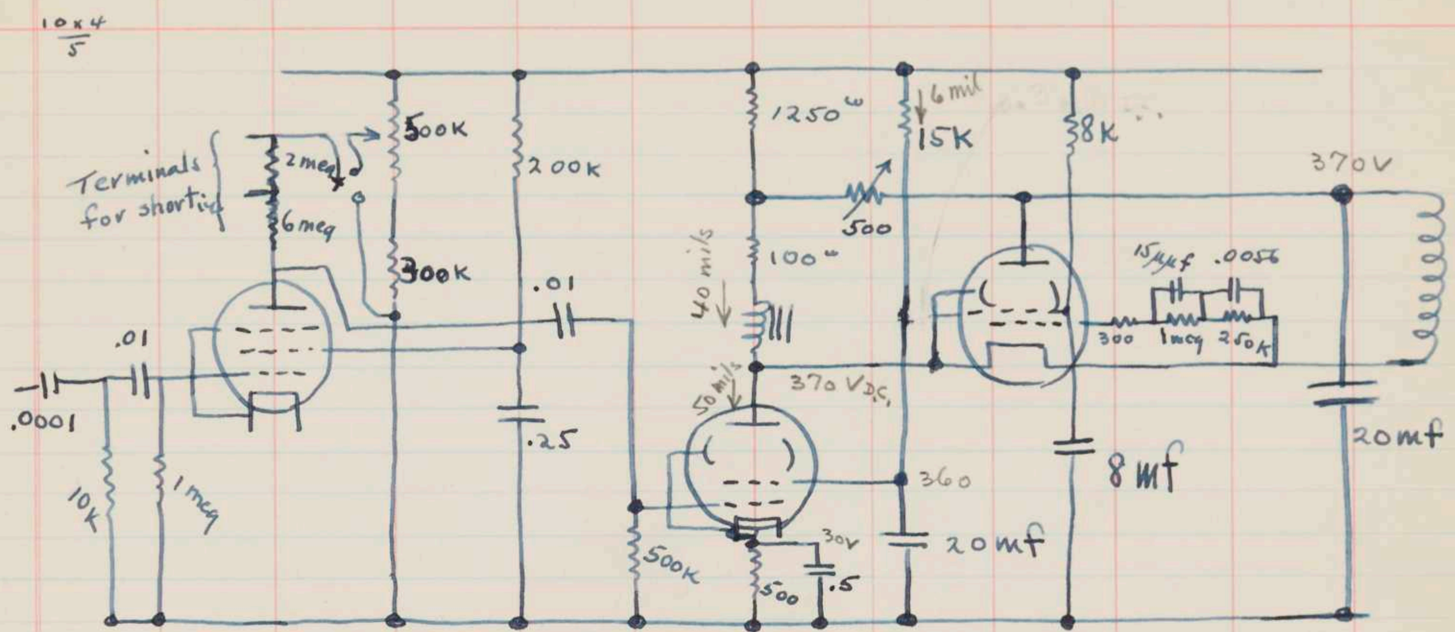
$$\int_0^\infty \bar{E}(\lambda)\, R_D(\lambda)\, d\lambda = \text{amp for source}$$

$$\frac{\int_0^\infty \bar{E}(\lambda)\, R_D(\lambda)\, d\lambda}{\int_0^\infty \bar{E}(\lambda)\, d\lambda} = \left[\frac{\text{amp}}{\text{watts}}\right]_{\text{for source and det.}}$$

i $\times 10^3$	R_ω		ΔR
26.18	39		
19.67	51.9		13
15.02	67.9		16
11.71	87.0		19.1
9.25	110		23
7.45	137		27

Studies of Sweep circuits to try to get more uniform coverage of screen. 4/15/42

WBW
W.H.



Tro 3400

Pyrex

50

L.N.

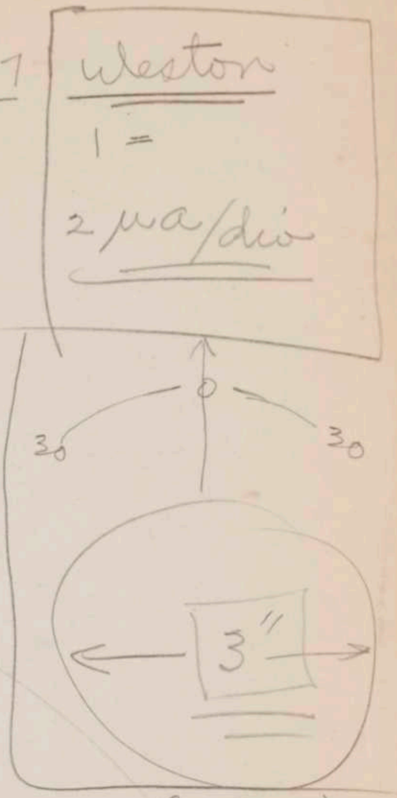
	Scale		Coil
50	5 μa		20
950	1 " "		250
2400	.5 " "	15 div	1000

[82150-d]

2

$15

1.7



(23 ω)

82150-d

142

Standard cell

Eppley

Weston — $25 — 1.01865 — 100 ω → 100 μa

Student $13 1.018 — 500 ω — 30 μa

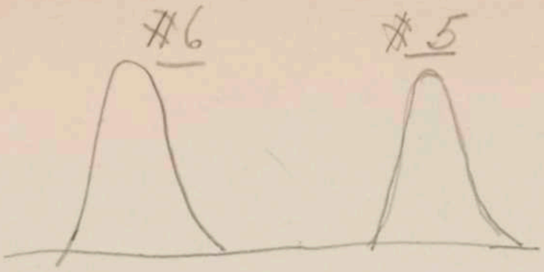
79425

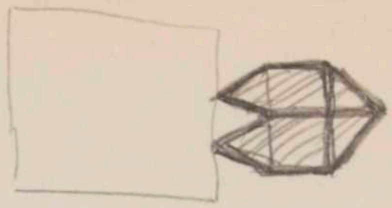
Round 12344-C $7.50

Corex fused ½ hold 2½ cc

300 mμ. 70%

330 " "



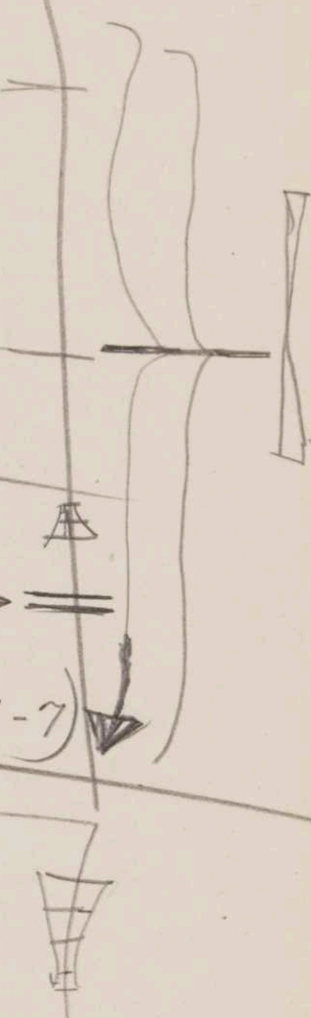


9/12/41 Curve #6

12/8/41 " #6

3/5/42 " #5

LM 407U (5-104-N-7)



5-4 Photo Surface

RCA L. E. Swedland

Cathode Ray Eng

Ham 6-8000