HAROLD E. EDGERTON

PAPERS

MC 25

Series III

Laboratory Notebooks

Number 3

Dated Feb. 15, 1930 to June 16, 1931

NOTEBOOK S-3.

Massachusetts Institute of Technology

COMPUTATION BOOK

NAME	Number
HAROLD E EDGERTON	3

Course VI

Used from FEB 15 1930, to JUNE 16 1931.

Notebook # 3

Filming and Separation Record

____ unmounted photograph(s)

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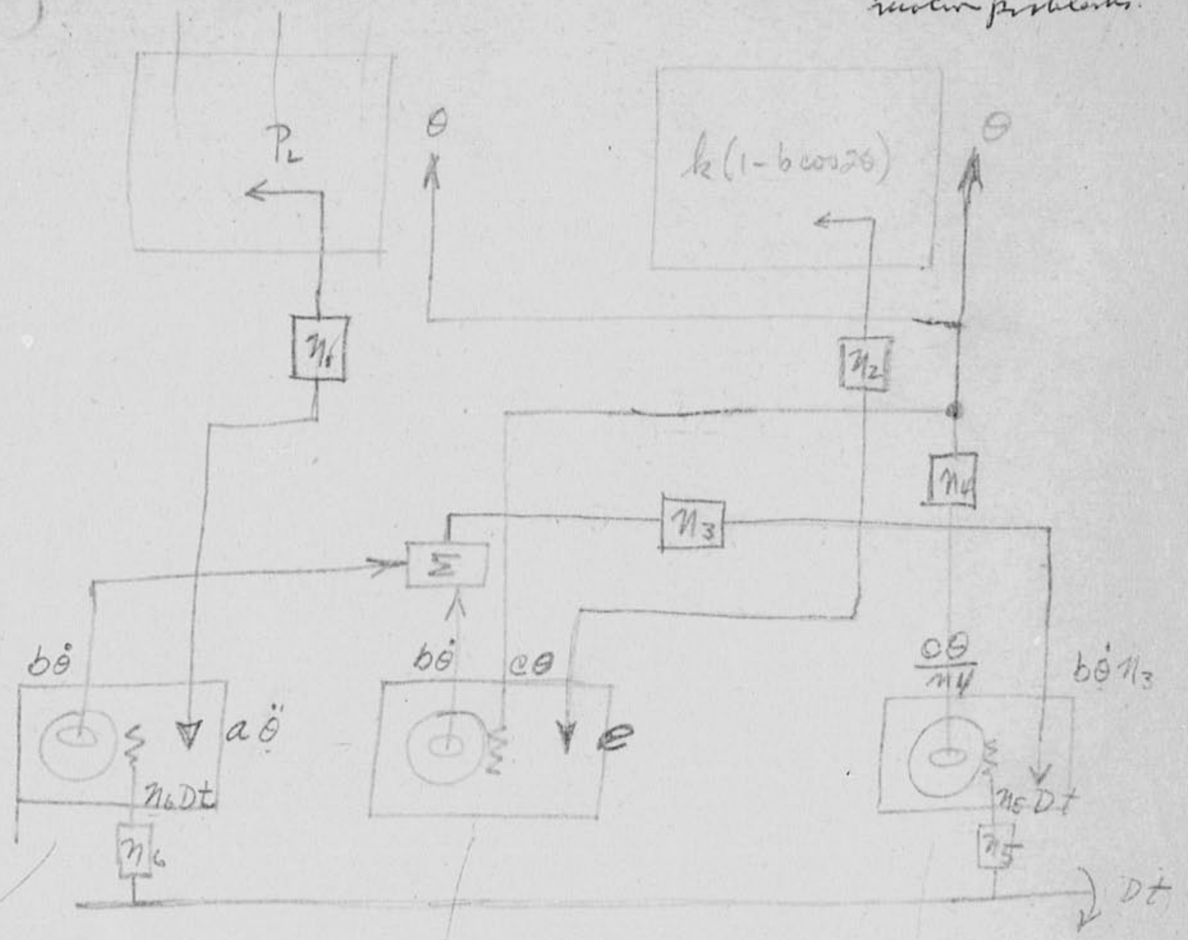
21 unmounted page(s)
(notes, drawings, letters, etc.)

was/were filmed where originally located between page ____ and ____.
inside front cover

Item(s) now housed in accompanying folder.

INTEGRAPH Solutions of synchr motor problems.



$a\ddot\theta < 40$ rev. ✓

$e < 40$ rev.

$b\dot\theta n_3 < 40$ rev.

$\cancel{b}\dot\theta = \frac{1}{32}\int \frac{a\ddot\theta}{b} n_6 D\,dt$ $\qquad \frac{a n_6 D}{32 b} = 1$

$\cancel{b}\dot\theta = \frac{1}{32}\int \frac{e c}{b} \frac{d\theta}{dt}\,dt$ $\qquad \frac{e c}{32 b} = 1$

$\frac{\cancel{c\theta}}{\cancel{n_4}} = \frac{1}{32} n_4 \int \frac{b\dot\theta}{c} n_3 n_5 D\,dt$ $\qquad \frac{b n_4 n_3 n_5 D}{32 c} = 1$

$\dot{\theta}_{max}$ = 20 units elect degs / x unit.

$b\, n_3\, 20 < 40$ rev.

$b < \frac{40}{n_3\, 20} = \frac{2}{n_3}$.

Let $n_3 = 1/4$

$b < \frac{2}{\frac{1}{4}} = 8$

(1) Let $n_6 = n_5 = 1$ $\quad \frac{a\, n_6\, D}{32 \times 8} = 1$

(2) $\quad \frac{e.c}{32 \times 8} = 1$

(3) $\quad \frac{8\, n_4\, n_5\, D}{32 \times 4\, c} = 1$

a, $\cancel{n_6}$, D, e, c, n_4, $\cancel{n_5}$ — 7

Let 6" = 1 unit on (P_2 table.)

$a = 120$ rev. $n_1 = 120\, n_1$ rev./unit

Let $n_1 = 1/4$ so $a = \frac{120}{4} = 30$ rev./unit

from (1) $\quad D = \frac{32 \times 8}{30 \cdot 1} =$

from (3) $\quad c = \frac{8\, n_4}{32 \times 4}\left(\frac{32 \times 8}{30}\right) = \frac{8^2}{\cancel{32} \times 4 \times 2} \frac{\cancel{32} \times 8^2}{30} = \frac{8}{30}$

Let $n_4 = 1/2$

$k = .05$ units

$ke = .05 \times 60 \times 32$
$= 120$

from (2) $\quad e = \frac{32 \times 8^2\, 30}{8} = 30 \times 32$ rev/unit. $\quad$ 240

Let $e = \frac{30 \times \cancel{32}}{\cancel{2}}$

$c = \frac{\text{--}}{30} =$

$n_4 = \frac{32 \times 4 \times c}{8 D} = \frac{32 \times 4 \times 32 \times 8}{8 \times 30 \times D}$

but $D = \frac{32 \times 8}{30}$

$n_4 = \frac{\overset{16}{\cancel{32}} \times \cancel{4} \times \cancel{32} \times \cancel{8} \times \cancel{30}}{\cancel{8}_2 \times \cancel{30} \times \cancel{32} \times \cancel{8}} = 16$?

should be 8?

Let $e = \frac{30 \times 32}{2}$

$c = \frac{\cancel{32} \times 8 \times \cancel{2}}{\underset{15}{\cancel{30}} \times \cancel{32}} \quad \frac{8}{15}$

$n_4 = \frac{32 \times 4 \times 8}{8 D \ 15} = \frac{\cancel{32} \times \cancel{4} \times \cancel{8} \ \cancel{30}^2}{\underset{2}{\cancel{8}} \times \cancel{15} \ \cancel{32} \times \cancel{8}} = 1$

---

but if $n_5 = 1/2$

$e = 8/15$

$n_4 = \frac{32 \times 4 \times c}{8 \ n_5 \times D} = \frac{\cancel{32} \times \cancel{4} \times \cancel{8} \ \cancel{30}^{15}}{\cancel{8} \ \cancel{32} \times \underset{2}{\cancel{8}} \times 15 \ \cancel{15} \ \frac{1}{2}} = 2$

trial II.

Let $n_6 = 1/2$.

$a = 30$
$b = 8$

$$D = \frac{32 \times 8}{a\, n_6} = \frac{32 \times 8 \times 2}{30}$$

$$\text{Let } e = \frac{30 \times 32}{2}$$

$$\text{so} \quad c = \frac{32 \times 8}{e} = \frac{\cancel{32} \times 8^{2}}{30 \times \cancel{32}} = \frac{16}{30}.$$

$$n_4 = \frac{32 \times 4 \times c}{8\, n_5\, D} = \frac{\cancel{32} \times \cancel{4} \times 16\ \cancel{30}}{8 \times \cancel{32} \times \cancel{8}\ \cancel{30} \times 2} = \frac{1}{2}$$

Let $n_5 = 1$

$\frac{16}{30}$ rev/min.

$\frac{16}{2 \times 30}$ in/min

$$\frac{\overset{12}{360} \times \overset{4}{\cancel{16}}}{\underset{5}{\cancel{30}} \times \cancel{32}} = \frac{4}{5} =$$

$a = 30$

$b = 8$

$D = \frac{32 \times 8}{15}$

$e = 15 \times 32$

$c = 16/30$

$n_1 = \boxed{1/4}$

$n_2 = 1/4$

$n_3 = 1/4$

$n_4 = 1/2$

$n_- = 1$

Trial II.

8.

~~Let $b = 16$ —— $A_5 = \frac{1}{8}$~~

trial III

Let $c = \frac{32}{30}$

and e must equal $\frac{30 \times 32}{2}$

$$b = \frac{ec}{32} = \frac{32}{\cancel{30}} \frac{\cancel{30} \times \cancel{32}}{2} \frac{1}{\cancel{32}} = 16$$

and $a = 30$

$$\frac{a\, n_6 D}{32 b} = 1$$

try $n_4 = 1/2$

$$\frac{e c}{32 b} = 1$$

$n_3 < \frac{40}{20 b} = \frac{2}{16} = \frac{1}{8}$

$$\frac{b\, n_4 n_3 n_5 D}{32 c} = 1$$

Let $n_3 = \frac{1}{8}$

Let $n_5 = 1$

$$D = 32 \frac{32}{30} \frac{\cancel{2}}{\cancel{16}} \cancel{8} = \frac{32 \times 32}{30}$$

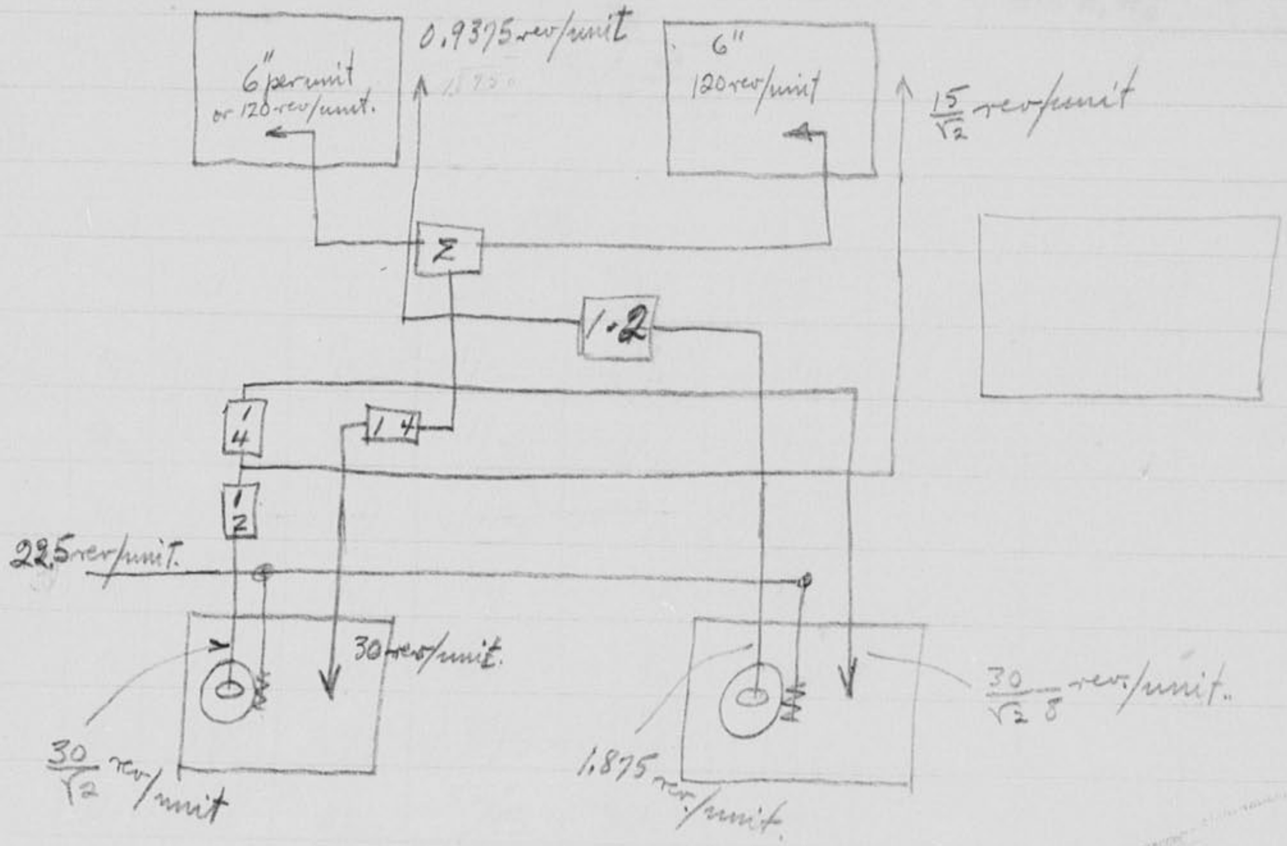
$$n_6 = \frac{32 b}{D a} = \frac{\cancel{32}\ 16\ \cancel{30}}{\cancel{32} \times 32\ \cancel{30}} = \frac{1}{2}$$

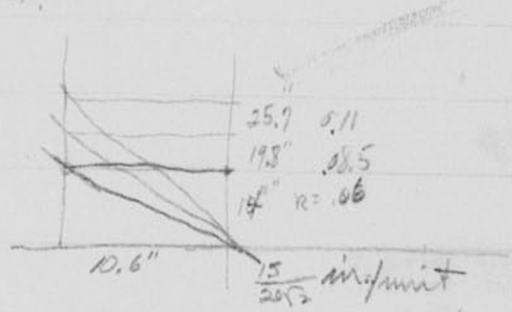
$a = 30$
$b = 16$
$D = \frac{32 \times 32}{30}$
$e = \frac{30 \times 32}{2}$
$c = 32/30$
$n_1 = 1/4$
$n_2 = 1/4$
$n_3 = 1/8$
$n_4 = 1/2$
$n_5 = 1$
$n_6 = 1/2$

When $k = .05$ $k \times \frac{30 \times 32}{2} n_2$

$$.1 \times \frac{30 \times \cancel{32}^{4}}{\cancel{2}} \frac{1}{\cancel{4}} = 120 \text{ rev}$$

III.





.53 in. unit

$\frac{P_L}{P_m} = k\,\frac{d\theta}{dt}$

$14 = .06\,\frac{20}{7}$

$$a = \frac{120}{\cancel{n_1}} n_6 \qquad c = \sqrt{\frac{ea}{n_1 n_2}}$$

$.9375 \frac{9.39}{8.45}$ 1.12 $\sqrt{\ } = 1.058$

$$e = \frac{0.9375}{n_5} \qquad c n_1 n_2 = \sqrt{e a n_1 n_2}$$

$$D = 32\sqrt{\frac{e}{a n_1 n_2}}$$

omit ~~IV~~

	I	II	III	V	VI	VII	VIII
n_1	1/32	1/2	1/2	→ 1/4	1/4		
n_2		1/4	1/4	→ 1/4	1/4		
n_5	1/8	1/4	1/2	→ 1/2	1/4		
n_6	1/8	1/4	1/4	→ 1/4	1/4		
a	15	30	30	→ 30	30		
e	7.5	3.75	1.875	→ 2.085 ~~1.875~~	3.75		
time of solution D	128	32	$32/\sqrt{2}$	32	$32\sqrt{2}$		
c		30	$30/\sqrt{2}$	30			
Travel of B unit $c n_1 n_2$	1.88	3.75	2.66.	1.88	2.66		
Slip Scale in/unit			.53	* 3/8 ~~.375~~ 0.3995			

← 2

April 3, 1931

$20 \times \frac{9.39}{180} = 1.043$ rev/unit

$e = \frac{1.043}{1/2} = 2.085$ rev/unit

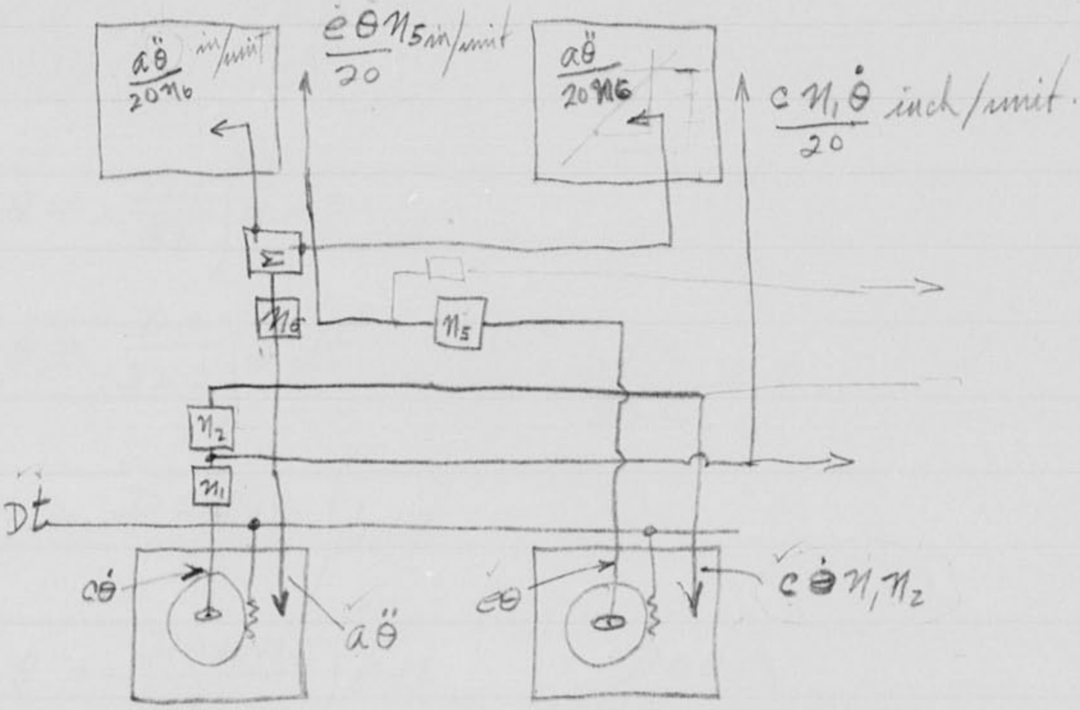
$c = \sqrt{\frac{ea}{n_1 n_2}} = \sqrt{16 \; 2.085 \; 30} = 4\sqrt{62.5}$

$= 4 \times 7.90 = 31.6$ rev/unit

$c \times \frac{1}{4} = 31.6 \frac{1}{4} = 7.9$ rev/unit

$\frac{7.9}{20} = 0.395$ in./unit

$\frac{a}{n_6} = k e n_5$



$a\ddot{\theta} \not< 40$ rev.

$c\dot{\theta}\, n_1 n_2 \not< 40$ rev.

$\frac{c n_1 \dot{\theta}}{20} \not< 12'' \pm$

$$\dot{\theta} = \frac{Da}{32 e} \int \ddot{\theta}\, dt$$

$$\theta = \frac{c n_1 n_2 D}{32 e} \int \dot{\theta}\, dt$$

$$\theta = \frac{c n_1 n_2 D^2 a}{32^2\, c\, e} \iint \ddot{\theta}\, dt.$$

Conditions for scales is that $\frac{c n_1 n_2 D^2 a}{32^2 c\, e} = 1.$

Speed of solutions $\quad \ddot{\theta} = \left(\frac{c n_1 n_2 D^2 a}{32^2 c\, e}\right) \ddot{\theta} = k$

$$\frac{a\ddot{\theta}}{\cancel{20} n_6} = \frac{k\, n_5\, e\theta}{\cancel{20}}$$

$$\ddot{\theta} = \frac{n_6\, k\, n_5\, e}{a}\, \theta.$$

$$\ddot{\theta} = \frac{k\, n_5\, e\, n_6}{a}\, \theta.$$

At one point

$$\frac{a\ddot{\theta}}{20\,n_6} = k\,\frac{e\theta n_5}{20}$$

(1)

$$c\dot{\theta} = \frac{Da}{32}\int \ddot{\theta}\,dt$$

$$\dot{\theta} = \frac{Da}{32c}\int \ddot{\theta}\,dt \qquad \therefore \frac{Da}{32c} = 1$$

$D = \frac{32c}{a}$

$$e\theta = -\frac{Dcn_1n_2}{32}\int \dot{\theta}\,dt$$

$$\theta = -\frac{Dcn_1n_2}{32e}\int \dot{\theta}\,dt \qquad \therefore \frac{Dcn_1n_2}{32e} = 1$$

$$\theta = -\frac{D^2acn_1n_2}{32^2ce}\iint \ddot{\theta}\,dt^2$$

$$\ddot{\theta} = k\,\frac{en_5n_6}{a}\,\theta \qquad k \text{ is geometrical slope}$$

$$\theta = -k\,\frac{D^2acn_1n_2}{32^2ce}\cdot\frac{en_5n_6}{a}\iint \theta\,dt^2$$

$$\ddot{\theta} = -k\,\frac{D^2n_1n_2n_5n_6}{32^2}\,\theta$$

If $\theta = A\sin(\omega t + \alpha)$

$$\omega = \sqrt{k\,\frac{D^2n_1n_2n_5n_6}{32^2}}$$

T_{sec} for 1 period $= \frac{120\pi}{N}D$

$\frac{60}{N}D$

$T = \frac{2\pi}{\omega}$ in terms of t

T_D in terms of variable (Dt) is D times T

$$T_{time} \text{ in seconds} = \frac{\text{sec.}}{\text{rev. of time sh.}} \times \frac{\text{rev.}}{\text{unit of } \left.\begin{matrix} Dt \\ t \end{matrix}\right\}} \times \frac{\text{units of } \left.\begin{matrix} Dt \\ t \end{matrix}\right\}}{\text{unit of } \left.\begin{matrix} T_D \\ T \end{matrix}\right\}}$$

In example set up for backlash test

$k = 1 \qquad n_6 = 1 \qquad n_5 = \frac{1}{4}$

$\frac{a}{n_6} = k e n_5 \qquad a = \frac{e}{4}$

$n_1 n_2 = \frac{1}{4}$

$C = \frac{Da}{32} \qquad c = \frac{32 \cdot e \cdot 4}{D} = \frac{32 \cdot 16 a}{D}$

$\frac{Da}{32} = \frac{32 \cdot 16\, a}{D}$

$D^2 = 32^2 \cdot 16$

$D = 4 \times 32 = 128$

$C = \frac{128a}{32} = 4a = e$

time of oscillation in sec. = 88

Speed of time shaft = N rpm $\qquad \frac{\text{sec}}{\text{rev}} = \frac{60}{N}$

$88 = \frac{60}{N} 128 \times 2\pi$

$N = \frac{60 \times 128 \times 2\pi}{88} = \frac{60 \times 32\pi}{11} = \frac{1920\pi}{11} = 550$ rpm.

Motor speed = 3.75 × 550

= 2070 r.p.m.

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(3)

Edgerton's problem (New ratios (II))

$$\frac{e\,n_5}{20} = \frac{0.9375}{20} = 0.046875 \text{ in/deg.}$$

✓ $e = 4 \times 0.9375 = 3.75$ rev/deg @ output of #2 integ.

$$\frac{a}{20\,n_6} = 6 \text{ inches per unit torque}$$

$n_6 = \frac{1}{4}$ ✓ $a = \frac{20 \times 6}{4} = 30$ rev of #1 lead sc. / unit torque

$$\frac{D\,c\,n_1 n_2}{32\,e} = 1 \qquad n_1 n_2 = \frac{1}{8}$$

$$D = \frac{32\,e}{n_1 n_2\, c} = \frac{32 \times 3.75 \times 8}{c} = \frac{256 \times 3.75}{c}$$

$$= \frac{960}{c}$$

$$D = \frac{32\,c}{a} = \frac{32}{30}c \qquad c = \frac{30}{32}D$$

$$D = \frac{960}{\frac{30}{32}D} \qquad D^2 = \frac{32 \times 256 \times 3.75}{30}$$

$$D^2 = \frac{2^{13} \times 3.75}{30} = \frac{2^{12} \times 3.75}{15} = 2^{12} \times 0.25$$

$$= 2^{10}$$

✓ $D = 32$

✓ $c = 30$

Try in $c\,\dot\theta\,n_1 n_2 \leqq 40$ $\quad \cancel{e} = \frac{30}{8}\dot\theta = \frac{30 \times 16}{8} = 60$

Edgerton's problem

Take $e = 0.9375 \times 4 = 3.75$ rev./degree of θ on input

corresponds to input table $\angle$ scale 0.1

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New layout of ratios (II)

④

$$\omega^2 = k\,\frac{D^2 n_1 n_2 n_5 n_6}{32^2} = 1\,\frac{32^2}{32^2\times 8\times 4\times 4} = \frac{1}{128} = \frac{1}{8^2\cdot 2}$$

$$T = 2\pi 8\sqrt{2} = 16\sqrt{2}\pi = 71.\ \text{units of } t$$

$= 71\times 32$ revolutions

$= 2270$

$T = \frac{120\pi}{N}32$

$\frac{2270}{400} = 5.67$ min.

Old ratios (I) $n_6 = \frac{1}{8}$ $n_5 = \frac{1}{8}$

$n_1 n_2 = \frac{1}{32}$

$$\omega^2 = 1\,\frac{128^2}{32\times 8\times 8\cdot 32^2} = \frac{2^{14}}{2^{15+6}} = 2^{-7} = \frac{1}{128}$$

$$\omega = \frac{1}{8\sqrt{2}}$$

$$T = 2\pi 8\sqrt{2} = \underbrace{16\sqrt{2}\pi}_{71}\ \text{units of } t$$

$= 71\times 128$ revolutions of t shaft

Time in ~~min.~~ $= \frac{71\times 128}{400} = \frac{71\times 32}{100} = 22.7$ min.

$$T = \frac{120\pi}{N}128$$

Find to Harden Tabs

Scales III $\left(c_{III} = \frac{c_{II}}{\sqrt{2}}\right)$ (5)

$$\frac{Da}{32c} = 1 \qquad \frac{32 \times 30}{32 \times 30} = 1$$

$$\frac{Dc\, n_1 n_2}{32e} = 1 \qquad e\, n_5 = 0.9375 \qquad e = \frac{0.9375}{n_5}$$

Check on new Tabs

$$\frac{Dc\, n_1 n_2 n_5}{32 \times 0.9375} = 1 \qquad \frac{\cancel{32} \times 30}{\cancel{32} \times 0.9375 \times 8 \times 4} = 1$$

$$D = \frac{32c}{a}$$

$n_1 = \frac{1}{2}$

$n_2 = 1/4$

$$\frac{32c}{a} \cdot \frac{c\, n_1 n_2 n_5}{32 \times 0.9375} = 1$$

Take $c = \frac{30}{\sqrt{2}}$ find n_5

$$\frac{32}{30}\,\frac{30^2}{2}\,\frac{1}{8}\,\frac{n_5}{32 \times 0.9375} = 1$$

$$n_5 = \frac{\cancel{30} \times 2 \times 8 \times \cancel{32} \times 0.9375}{\cancel{32} \times \cancel{30^2}} = \frac{1}{2}$$

$$\omega^2 = k\,\frac{D^2 n_1 n_2 n_5 n_6}{32^2} = k\,\frac{32^2 c^2 \cdot n_1 n_2 n_5 n_6}{\cancel{32^2}\, a^2}$$

$$D = \frac{32 \cdot 30}{30 \cdot \sqrt{2}} = \frac{32}{\sqrt{2}}$$

$$T = \frac{120\pi}{N}\,\frac{32}{\sqrt{2}}$$

$$\frac{22.5\ 30\sqrt{2}}{32\ 30} = 1 \checkmark$$

$$\frac{22.5\ \cancel{30}}{32\ \sqrt{2}}\,\frac{1}{8}\,\frac{1}{1.875} = \frac{673.}{670} = 1.0 \checkmark$$

$c\, n_1 n_2\, \dot{\theta} < 40$ rev.

$\frac{30}{\sqrt{2}}\ \frac{1}{8}\ 17$

$$\frac{32 \cdot 30^2}{32 \times 8 \times 4 \times 0.9375} \approx 1$$

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(6)

Scales IV

Take $n_1 n_2 = \frac{1}{16}$ $c = 30\sqrt{2}$

$$\frac{32c}{a} \cdot \frac{c n_1 n_2 n_5}{32 \times 0.9375} = 1$$

$$\frac{32 \cdot 30^2 \cdot 2 \qquad n_5}{30 \quad \times 32 \times 0.9375 \times 16} = 1$$

$$n_5 = \frac{\cancel{30} \times \cancel{32} \times \cancel{16}^{8} \times 0.9375}{\cancel{32} \times 30^{\cancel{2}} \times \cancel{2}} = \frac{7.5}{30} = \frac{1}{4}$$

$$\omega^2 = k \frac{c^2 n_1 n_2 n_5 n_6}{a^2} \qquad D = \frac{32c}{a} = \frac{32 \cdot 30\sqrt{2}}{30} = 32\sqrt{2}$$

$$T_{sec} = \frac{60}{N} D \, 2\pi = \frac{120\pi D}{N}$$

$$= \frac{120\pi}{N} \; 32\sqrt{2}$$

$c n_1 n_2 \theta$

$\frac{30\sqrt{2}}{1} \frac{1}{16} \, 17 = 45$

$\frac{d\theta}{dt}\,dt.$

$$\theta = \int\left[\int P_L\,dt - \int k(1-b\cos 2\theta)\,\dot\theta\,dt\right] dt.$$

$\frac{d\theta}{dt}$

θ

$\dot\theta$

$\int P_L\,dt$

$k(1-b\cos 2\theta)$

$\int k(1-b\cos 2\theta)\,\dot\theta\,dt$

$\Sigma \quad \int P_L\,dt - \int k(1-b\cos 2\theta)\,\dot\theta\,dt \ldots$

θ

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apr 5

1.

$\ddot{\theta}_{max}$ is about 2 or less.

so $a < \frac{40}{2} = 20$ $\therefore$ let $a = \underline{16}$

Max for e units = 0.2

$e \times 0.2 < 40$ $e < \frac{40}{0.2} = 200.$ Let $e = \underline{\mathbf{128}}$

$\dot{\theta}$ max is about 20

$b\dot{\theta} < 40$ $b < \frac{40}{20} = 2.$ let $b = 2.$

$\underline{1}$ $1 = \frac{n_3 n_6 a D}{32 b} = \frac{n_3 n_6 16 D}{32 \times 2} = \boxed{\frac{n_3 n_6 D}{4}}$

2. $1 = \frac{n_7 e c}{b\, 32} = \frac{n_7\, 128\, c}{2\ 32} = \boxed{2 n_7 c.}$

3. $1 = \frac{n_4 n_5 b D}{32 e} = \frac{n_4 n_5\ 2\ D}{32\ e} = \boxed{\frac{n_4 n_5}{16} \frac{D}{c}}$

n_3 ✓
n_6 ✓
n_7
n_4
n_5 ✓
D
c

I Try $n_5 = 1$ $n_6 = 1$ $n_3 = 1/4$ $n_7 = 1/4$

1. $1 = \frac{n_3 n_6 D}{4} = \frac{1}{4} \frac{1\,D}{4}$ $D = 16.$

$n_5 = \frac{16 c}{D n_4}$

$= \frac{16\ 2\ 4}{64}$ 2

2. $1 = 2 n_7 c = 2 \frac{1}{4} c$ $c = 2.$

3. $1 = \frac{n_4 n_5}{16} \frac{D}{c} = \frac{n_4\ 1}{\cancel{16}} \frac{\cancel{16}}{2}$ $\underline{n_4 = 2.}$ but $n_4 \leqq \frac{1}{2}.$

II try $n_4 = 1/2$ which gives from 3 $\frac{D}{c} = \frac{16 \times 2}{n_5}$

Let $n_3 = n_7 = 1/4$

$n_6 = 1/4$

$D = \frac{4}{\frac{1}{4}\frac{1}{4}} = 16 \times 4 = 64$

$c = \frac{1}{2\, 1/4} = 2.$

$n_5 = \frac{c}{D} \frac{16 \times 2}{} = \frac{2}{64}\ 16 \times 2 = 1$ 2.

~~(2) $c = \frac{1}{2 n_7}$~~

~~$D = \frac{4}{n_3 n_6}$~~

D
c
n_5
n_6
n_7 –
n_3 –

3

✓

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III try $n_4 = 1/2$ (same as II)

Let $n_3 = n_7 = 1/2$

$n_6 = 1/2$

$c = \frac{1}{2\frac{1}{2}} = 1$

$D = \frac{4}{\frac{1}{2}\frac{1}{2}} = 16.$

$n_5 = \frac{32}{D} c = \frac{32 \cdot 1}{16} = 2.$

NG

IV try $n_4 = 1/\cancel{4}$

try $n_3 = n_7 = 1/4$

$n_6 = 1$

$\frac{n_3 n_6 D}{4} = 1$

$2 n_7 c = 1$

$\frac{1}{4 \times 16} n_5 \frac{D}{c} = 1$

$D = \frac{4}{\frac{1}{4} 1} = 16 \quad c = \frac{1}{2\frac{1}{4}} = 2$

$n_5 = 64 \frac{c}{D} = 64 \frac{2}{16} = 8.$ NG.

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check on case II

n_1

n_2

n_3 1/4

n_4 1/4

n_5 1

n_6 1/4

n_7 1/4

a 16

b 2

c 2

e 128

D 64

1. $1 = \frac{n_3 n_6 a D}{32 b} = \frac{1/4 \; 1/4 \; 16 \; 64}{32 \times 2} = 1$ ✓

2. $1 = \frac{n_7 e c}{b \, 32} = \frac{1/4 \; 128 \times 2}{2 \times 32} = 1$ ✓

3. $1 = \frac{n_4 n_5 b D}{32 c} = \frac{1/4 \; 1 \; 2 \; 64}{32 \times 2} = 2$ ✗

$\frac{400}{20} \overset{= 20 \text{ in min}}{\text{rev/min.}}$

1.043

~~$\frac{c}{32} = 1.043$ rev/unit~~

~~$c = \frac{1.043}{2} = .5$~~

V

$n_4 = \frac{1}{2}$ 1.056

$\frac{c}{n_4} = c \times 2 = \underline{\underline{2.086}}$ rev/unit.

$c = 1.043$ rev./unit

Quantities determined

$c = 1.043$ rev/unit.

$a = 16$ rev

$e = 128$ rev

$b = 2$ rev.

1. $1. = \frac{n_3 n_6 aD}{32b} = \frac{n_3 n_6 16 D}{32 \cdot 2} = \frac{n_3 n_6 D}{4}$

2 $\cancel{1}. = \frac{n_7 e c}{b\, 32} = \frac{n_7 \cancel{128}^{4}\, 1.043}{32\, b} = \frac{4 n_7 1.043}{2.}$

$n_7 = \frac{2}{\cancel{4}_{2}\, 1.043} = \frac{1}{2} \frac{1}{1.043}$

Replot ~~a~~ chart so that $c = 1.0$

Let $n_8 = 1$ $c = 1.0$ rev per unit. (elect deg).

or $\frac{1.0 \times 18\pi}{2\pi} = 9$ inches for 180 elect degrees.

Sent to Hayden Fab

4.

VI Quantities determined

$c = 1.0$

$a = 16$

$e = 128$

$b = 2$

1. $1 = \frac{n_3 n_6 a D}{32 b} = \frac{n_3 n_6 \cancel{16} D}{\cancel{32}_2 \; 2} = \frac{n_3 n_6 D}{4}$

2. $1 = \frac{n_7 e c}{b\,32} = \frac{n_7 \cancel{128}^{2} \times 1}{\cancel{2} \; \cancel{32}} = 2 n_7$

$$\boxed{n_7 = 1/2}$$

3. $1 = \frac{n_4 n_5 b D}{32\, c} = \frac{n_4 n_5 2 D}{\cancel{32}_{16} \times 1} = \frac{n_4 n_5 D}{16}$

(5 unknowns) $n_3\ n_4\ n_5\ n_6\ D$ (two equa)

Let $n_3 = 1/2$. $n_4 = 1/2$ $n_5 = 1$

from 3 $1 = \frac{1/2 \; 1}{16} D$ $D = 16 \times 2 = 32$.

from 1 $1 = \frac{\frac{1}{2} n_6 \cancel{32}^{\cancel{8}\,4}}{\cancel{4}} = 4 n_6$

$n_6 = 1/4$.

Retabulation

n_1	1/8
n_2	1/4
n_3	1/2
n_4	1/2
n_5	1
n_6	1/4
n_7	1/2
a	16
b	2
c	1
D	32
e	128

for $\frac{a\theta}{20 n_1} = \frac{1.6}{\cancel{20}} \cancel{8}^{4} = 6.4$ in per unit

$\frac{e}{n_2} = \frac{128}{20\, \cancel{1}/8} = \frac{128 \times \cancel{8}^{4}}{\cancel{20}} = 51.2$ in/unit

VII For cases where $k = 0.05$ as max.

Then $e = 256$.

a remains 16

b 2

c 1.

Unit equations $$1 = \frac{n_3 n_6 a D}{32 b} = \frac{n_3 n_6 \times 16 D}{\cancel{32}_2 \times 2} = \frac{n_3 n_6 D}{4}$$

$n_7 = 1/4$. $$1 = \frac{n_7 e c}{b 32} = \frac{n_7 256 \cdot 1}{2 \times 32} = n_7 4$$

$$1 = \frac{n_4 n_5 b D}{32 c} = \frac{n_5 n_4 2 D}{32 \times 1} = \frac{n_5 n_4 D}{16}$$

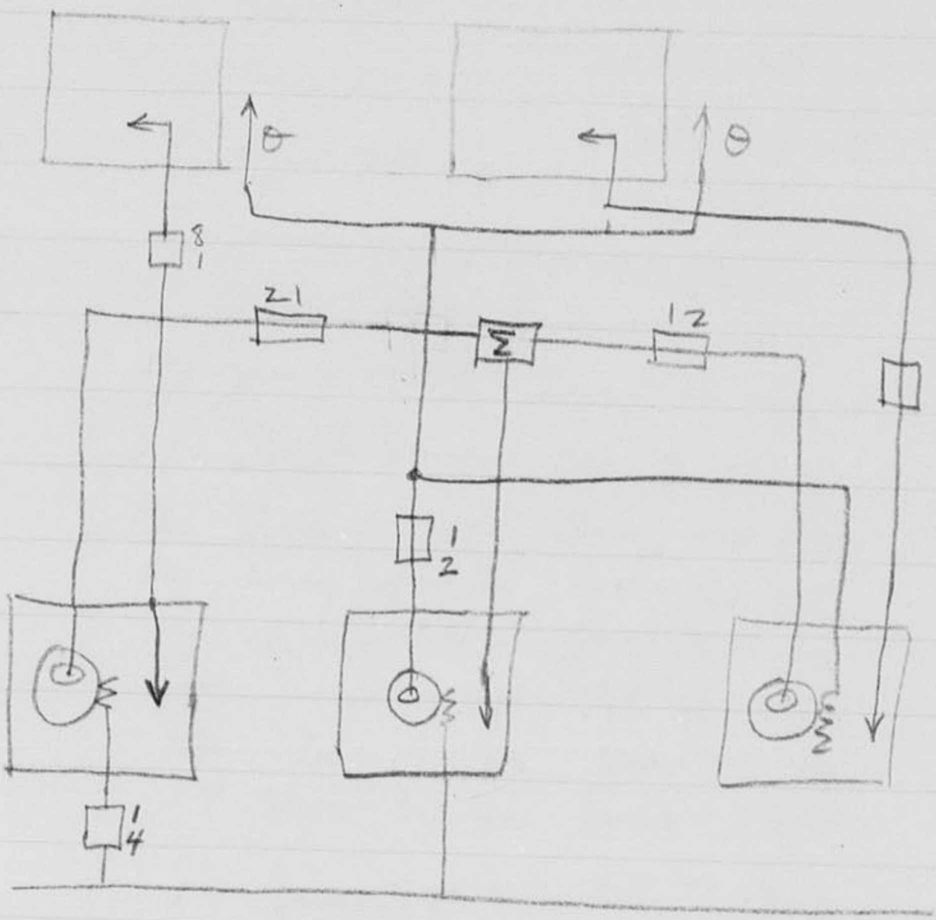
$$\frac{ds}{dt} + \frac{P_d}{P_j}(1 - b\cos 2\theta)s = \frac{P_L}{P_j'}$$

$$s = \cancel{f\theta \cdot t}\ \frac{d\theta}{dt}$$

$$\frac{d^2\theta}{dt^2} + \frac{P_d}{P_j}(1 - b\cos 2\theta)\frac{d\theta}{dt} = \frac{P_L}{P_j'}$$

$$A\frac{d^2q}{dt^2} + \frac{R}{L}\frac{dq}{dt} = \frac{E}{L}$$

Sent to Hayden Lab



Sent to Hayden Lab

Computation Apr 27 1981

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N.B. 3 Feb 15 30 June 16 31

T-II July 20 31 Jan 12 32

T-5 Oct 27 34 Aug 27 35

T-6 Aug 27 35 - Apr 25 36

7 Apr 28 36 - May 27 37

8 June 1 37 April 16 37

9 Apr 18 38 June 12 39

10 June 13 39 Sept 17 40

11 Sept 17 40 Dec 3 41

12 Dec 4 41 Aug 24 42

13 Aug 24 42 Mar 31 43

14 Apr 1 43 Jan 30 44

15 Jan 30 44 Feb 16 45

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19 June 18 48 Feb 7 1950

EG&G Dec 8 48 April 8, 1951

Underwater Photography Experiments U.P. Aug 4 52 Oct 19 1952

20 Feb 7 50 Dec 27 51

21 Dec 27 51 Jan 9 54

22 Jan 9 54 Apr 19 55

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24 Dec 19 56 Apr 29 58

25 Apr 29 58 May 14 60

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27 Jan 18 62 Nov 18 63

28 Nov 18 63 May 30 65

29 May 30 65 July 11 69

30 Oct 2 69 Jan 11 73

31 Jan 11 73 Aug 17 75

Ken Germeshausen Book 1 10-15-31 Jan-14-31

(small, red composition Book) over

H. Edgerton Jan 21 1967 (white comp'n book)
H. Edgerton June 24 1947 H Bard [illegible]
small composition book (B.W.)

HAROLD E. EDGERTON
52 MASS. AVE.
CAMBRIDGE MASS.
M.I.T. ROOM 4-210
FEB. 15, 1930.

SELF-HUNTING OF SYNCHRONOUS MACHINES.

p102-105 Strobs

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

COMPUTATION BOOK

GENERAL INSTRUCTIONS

In all work in which *accuracy* and *ease of reference* are important, much depends upon carrying out the computation in a systematic manner. The following instructions, taken from the *Engineering Department Figuring Book of the Allis-Chalmers Co., serve as a guide in this matter.*

"All computations, of whatever kind, are to be made in these books, except in cases where special blanks may be provided for specific kinds of computation. Computations may be made in ink or pencil, whichever may be more convenient. Pencil figuring should be done with a soft pencil. All the work of computation should be done in these books, including all detail figuring."

"Each subject should begin on a new page, no matter how much space may be left on the previous page. The subject, with the date of beginning it, should be plainly written at the top of the first page of the subject."

"Work should be done systematically, and as neatly as consistent with rapidity. The books are, however, intended for convenience, and no unnecessary work should be done for sake of appearance only. Errors should be crossed off instead of erased, except where the latter will facilitate the work. Work should not be crowded. Paper costs less than the time which would be expended in attempting to economize space in making erasures."

"Where curves drawn on section paper (or sketches) are necessary parts of a computation, they should be pasted in the book, except where specifically otherwise provided for."

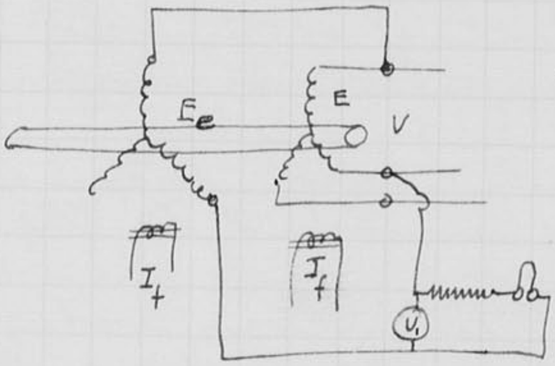
"Computations should be indexed, in the back of the book, by the person using the book."
* * * * * * *"

Harold E. Edgerton

Feb. 15, 1930
H. E. Edgerton

Oscillographic Measurement of the Angular Displacement in a Syn. Machine.

An extra synchronous machine on the shaft of a machine being tested gives a voltage which ~~is in~~ has a definite relationship with the induced emf. E of that machine ~~being tested since~~ since the field pole have a rigid relationship. The open-circuit voltage from this extra machine is combined vectorially with the terminal ~~al~~ voltage of the machine under test and a trigonometric 3 voltage problem gives the angular displacement.

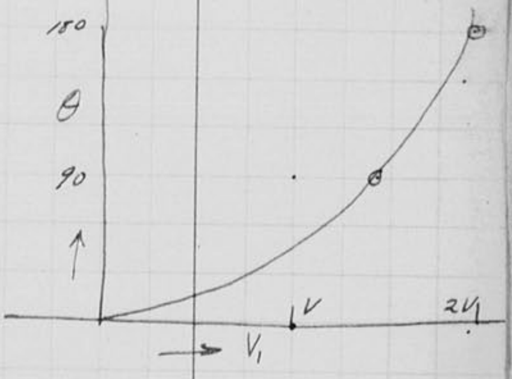


field poles of both machines in line.

If E_e and V are not equal then $\theta = \cos^{-1} \frac{V^2 + E_e^2 - V_1^2}{2 E_e V}$

When E_e and V are equal then

$$\theta = \cos^{-1} \frac{2V^2 - V_1}{2V^2} = \underline{\cos^{-1} 1 - \frac{V_1^2}{2V^2}}$$



This method has been used in the past with great success.

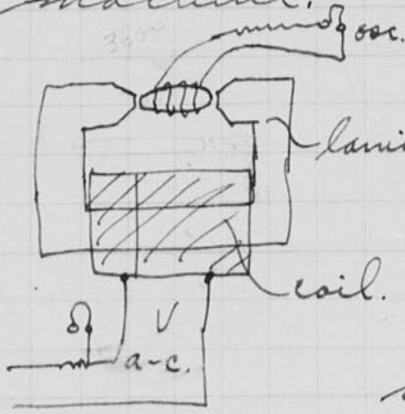
When the rotor is slipping, for instance during a transient following a sudden load, then the length of E_e depends directly upon the speed and some small errors are introduced. The expression for angle is then

$\theta = \cos^{-1} \frac{V^2 + (1-s)^2 E_e^2 - V_1^2}{2 E_e V (1-s)}$ where s is the slip. The slip is usually less than 2% so this is ordinarily neglected.

Feb 15 1930
H. Edgerton

Angle Measurement.

I had Mr. Kershaw build me a device which I hoped would aid in measuring angle with the oscillograph. This was to be a variable reluctance motor, its stator supplied by a.c. from the terminals, and its rotor circuit to be connected to an oscillograph vibrator. A sketch is shown of the machine. It was driven at 3600 r.p.m. by a 2:1 gear on a 1800 r.p.m. set in the dynamo laboratory (Sine wave generator set 99 a.b.c.).



Needless to say the output voltage of the rotor was of a very peculiar shape. The current input was also interesting and offers ~~some~~ possibility of future development. The current to the exciting a.c. coil has a nick in it every time that the eccentric rotor lines up with the pole faces. If the speed is constant this will occur at the same place on the current wave. Otherwise it will occur at different places and its position will depend upon the relative positions of the rotor and the terminal voltage.

Trouble was experienced with the copper ~~brushes~~ that were used and finally caused the experiment to be discontinued after four osc. were taken.

Data for osc.

Osc. 1. Chattering brushes on rotor gave poor record. Film also too slow.

Osc. 2. Poor Focus. Wave interfere. Too slow drum speed.

Osc. 3. O.K. on page 5.

Osc 4. Focus poor.

Angle voltage V, as explained on page 3 is shown on all osc.

Notebook # 3

Filming and Separation Record

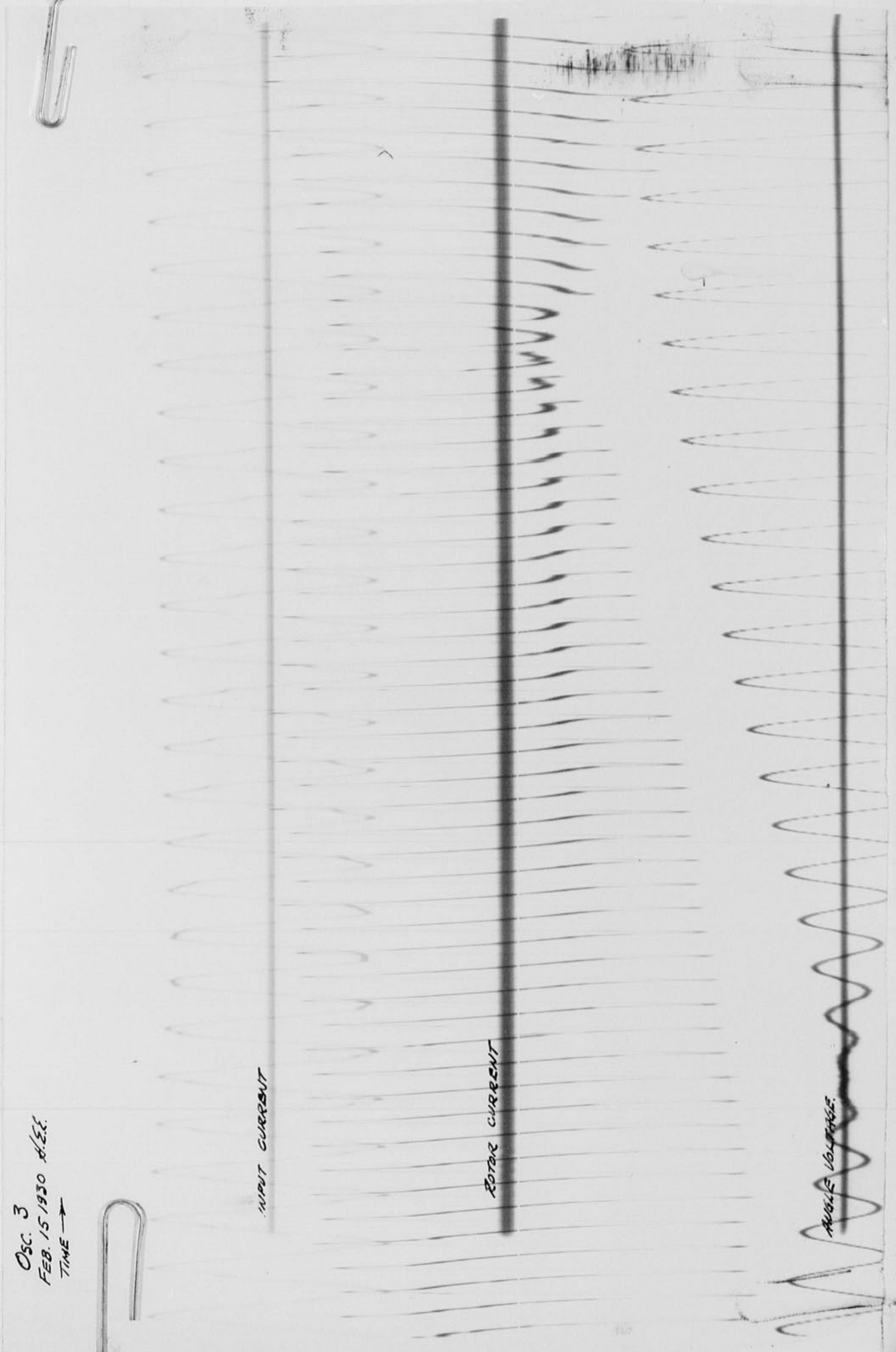
1 unmounted photograph(s)

____ negative strip(s)

____ unmounted page(s)
(notes, drawings, letters, etc.)

was/were filmed where originally located between page 4 and 5.

Item(s) now housed in accompanying folder.



Osc. 3
FEB. 15 1930 H.E.E.
TIME →

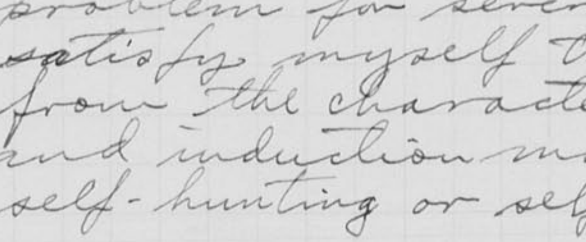
Feb. 21, 1930
H. E. Edgerton.

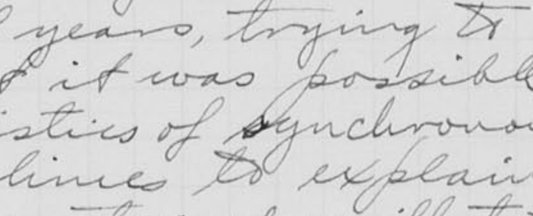
Source of Energy for Self Oscillations of Synchronous Machines.

A recent paper by Nickle and Pierce in the A.I.E.E. blames self hunting ~~to~~ on armature resistance. The unbalance of the rotor circuit is also considered and it is noted that pole face damping windings in the quadrature axis suppresses the possibility of self-oscillation. No physical picture was given in this paper of the mechanism whereby a synchronous machine should hunt accumulatively. Our common reasoning powers tell that if a winding on the rotor is oscillated back and forth during an oscillation, the induced currents from Len's law always oppose any change of position. Such an action would tend to reduce oscillations.

I have been thinking about this problem for several years, trying to satisfy myself that it was possible from the characteristics of synchronous and induction machines to explain self-hunting or self sustained oscillations.

My present opinion is that conditions for negative damping are only possible under conditions of unbalance on the rotor circuit. A rotor that is single phase has a torque that pulsates at double slip frequency. It is a maximum when the coil is cutting the maximum flux of the rotating field. It is also a minimum when not cutting the rotating field.





single phase rotor.

As shown in the sketch on the preceding page this torque due to a single phase winding is a minimum at zero angular displacement. If the currents in the single phase rotor effect the rotating field, ϕ, then this field can be represented by two oppositely rotating fields. this is necessary since the flux of the rotating field is pulsating.

The positively rotating field reacts with the field winding and gives positive damping acording to some law as the $\sin^2\theta$ as a function of angle and directly proportional to the slip for small values.

The negative field, however is in the opposite sense always to the positive and due to ~~#~~ circuit requirements does not have its maximum at the same time the positive field lines up with the coil. this being true the negative field at small angles is in such a direction as to give torque which appears to push instead of pull as a function of slip. this causes oscillations to build up. they will continue to increase in magnitude until large enough angles are reached in the course of the swinging where the positive damping again occurs.

Mechanical-Electrical Torque Equation.

Feb 23 1930
H. E. Edgerton

The swinging of a synchronous machine is always in accord with the differential equation that states the sum of the various mechanical and electrical torques that exist during the disturbance. This equation is of the form:

$$P_j \frac{d^2\theta}{dt^2} + f(\theta)\cdot\cancel{P}\left(\frac{d\theta}{dt}\right) + f_a(\theta) = \text{load torque.}$$

In an ideal machine with negligible armature resistance, a smooth rotor, and for small values of slip, this reduces to approximately the following:

$$P_j \frac{d^2\theta}{dt^2} + P_d \frac{d\theta}{dt} + P_m \sin\theta = \text{load torque.}$$

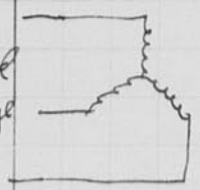
The term $P_d \frac{d\theta}{dt}$ is such that it always opposes any force that tries to change the speed of the machine from synchronism. This effect then in a machine with a balanced rotor circuit always tends to damp out oscillations. Such damping is termed by defination as being positive.

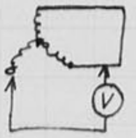
In order to get self-oscillations this force must have a negative sense some of the time since there can be no source of oscillation in the synchronizing or inertia terms of the differential equations. Dreyfus points out this fact. A rotor with a single phase winding will give this condition for small angular displacements.

Induction Motor with a Single-Phase Rotor.

Feb 23 1930
H. E. Edgerton

Balanced 3φ voltage supply V volts/ph.





From the open phase of the rotor to the short circuited pair there will be a voltage of slip frequency. This may be split up into its positive and negative sequence components by Fortescue's method of Symmetrical phase components.

Since the current in the open circuited phase is zero the sum of the positive and negative sequence currents are zero in this phase and thus equal to each other in magnitude but 180° in phase

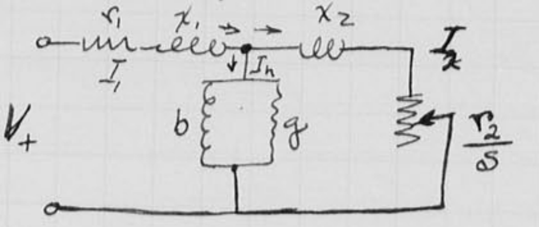
$I = I_{2+} + I_{2-} = 0$ where the 2 refers to the rotor circuit.

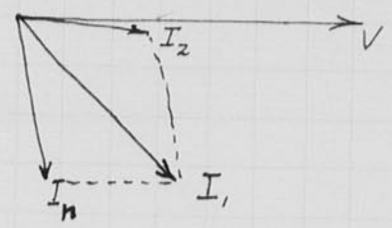
I think that this problem can be best analysed by considering that the stator has two components of voltage applied to it. Each will be polyphase and balanced. One will be the impressed emf, V. the other will depend upon the slip at ~~to~~ which the rotor is considered. It will be of such a value that the rotor current in one phase is zero. Such a requirement states that this fictitional voltage shall have a freq. of $(1-2S)f$ where S is the slip.

The stator current will be the sum of the two current components and since they are at different frequencies the total stator current will contain beats which occur in the different phases in rotation. I know this to be the case since I have observed it in the laboratory, both with meters and with the oscillograph.

Feb 23 1930
H. E. Edgerton

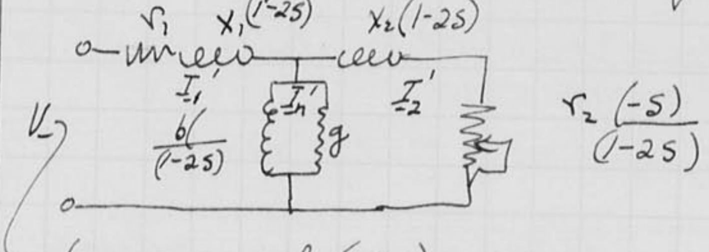
Equivalent Circuit for impressed voltage V.





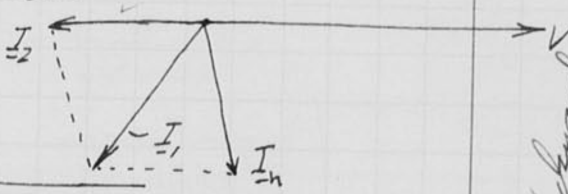
$$I_{+2} = \frac{(V_+ - I_n Z_+)}{r_1 + \frac{r_2}{s} + j(x_2 + x_1)}$$

Equivalent circuit for 1-2s voltage



Generator action for slips from 0 to .5. Motor then on down to slip of 1. or stand still.

frequency of (1-2s) times that of V_+



$$I'_{-2} = \frac{V_- - I_{-n} Z_-}{r_1 - \frac{r_2 s}{1-2s} + j\left[x_2(1-2s) + x_1(1-2s)\right]}$$

These two currents in the rotor winding are to be equal and opposite in one phase that is open.

$I_{-2} = I_{+2}$ from the above equations we can find V_- in terms of V_+ and the slip.

$$V_- - I_{-n} Z_- = \frac{Z_{-T}\,(V_+ - I_{+n} Z_+)}{Z_{+T}} = (V_+ - I_{+n} Z_+)\,\frac{\overbrace{\left(r_1 - \frac{r_2 s}{1-2s}\right) + j(1-2s)(x_1 + x_2)}^{= Z_{-T}}}{\underbrace{\left(r_1 + \frac{r_2}{s}\right) + j(x_1 + x_2)}_{= Z_{+T}}}$$

$$\underline{\underline{V_- = (V_+ - I_{+n} Z_+)\frac{Z_{-T}}{Z_{+T}} + I_{-n} Z_-}}$$

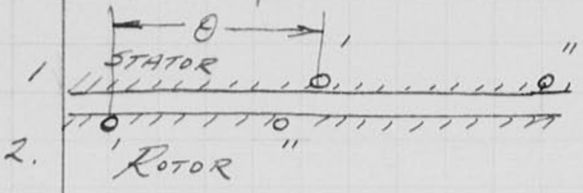
$Z_+ = r_1 + j x_1$

$Z_- = r_1 + j x_1 (1-2s)$

This scheme is not so good. The voltage for the backward flux component should be found in the rotor. Feb. 24, 1930.

Differential equation of a two phase machine and the reduction of these equations to a simple form.

Feb 24 1930 H. E. Edgerton



Sinusoidal flux is assumed in this treatment. The air gap is also uniform and the iron has a constant permeability.

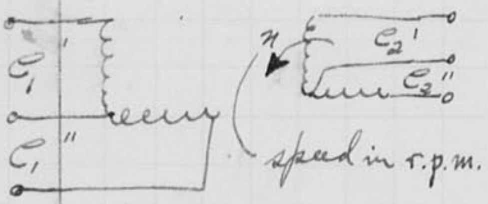
Voltage drops around phase one of the stator.

$$e_1' = r_1 i_1' + L_1 p i_1' + M p i_2' \cos\theta + M p i_2'' \cos\theta + \tfrac{\pi}{2} \qquad (1)$$

phase 2. $$e_1'' = r_1 i_1'' + L_1 p i_1'' + M p i_2'' \cos\theta + M p i_2' \cos\theta - \tfrac{\pi}{2} \qquad (2)$$

Rotor ph. 1. $$e_2' = r_2 i_2' + L_2 p i_2' + M p i_1' M\cos\theta + M p i_1'' M\cos\theta - \pi/2 \qquad (3)$$

ph 2. $$e_2'' = r_2 i_2'' + L_2 p i_2'' + M p i_1'' M\cos\theta + M p i_1' M\cos\theta + \pi/2 \qquad (4)$$



These may be reduced from four equations and four unknowns to two equations, two unknowns by splitting the currents into components.

In order to do this let:

$i_1' = i_{+1} + i_{-1}$ $\quad i_2' = i_{+2} + i_{-2}$ $\quad e_1' = e_{+1} + e_{-1}$

and $i_1'' = -j i_{+1} + j i_{-1}$ $\quad i_2'' = -j i_{+2} + j i_{-2}$. $\quad e_1'' = -j e_{+1} + j e_{-1}$

$e_2' = e_{+2} + e_{-2}$

$e_2'' = -j e_{+2} + j e_{-2}$

This change of variables gives the differential equations a new form wherein there are only ~~~~ two variables and two equations

$$e_{+1} = (r_1 + L_1 p)\, i'_{+1} + M p\, i'_{+2}\, \varepsilon^{j\theta}$$
$$e_{-1} = (r_1 + L_1 p)\, i'_{-1} + M p\, i'_{-2}\, \varepsilon^{-j\theta}$$

$$e_{+2} = (r_2 + L_2 p)\, i'_{+2} + M p\, i'_{+1}\, \varepsilon^{-j\theta}$$
$$e_{-2} = (r_2 + L_2 p)\, i'_{-2} + M p\, i'_{-1}\, \varepsilon^{j\theta}$$

Notice the change of sign for the stator and rotor equations is only in the exponent.

Preliminary proof   Subject to revision

EDGERTON

Notebook # 3

Filming and Separation Record

____ unmounted photograph(s)

____ negative strip(s)

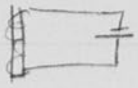
13 unmounted page(s) 12 page reprint with one page
(notes, drawings, letters, etc.) of notes inserted

was/were filmed where originally located between page 12 and 13.

Item(s) now housed in accompanying folder.

EDGERTON

Nov. 26, 1930.



Round Rotor

No excitation in quad axis.

no neut current

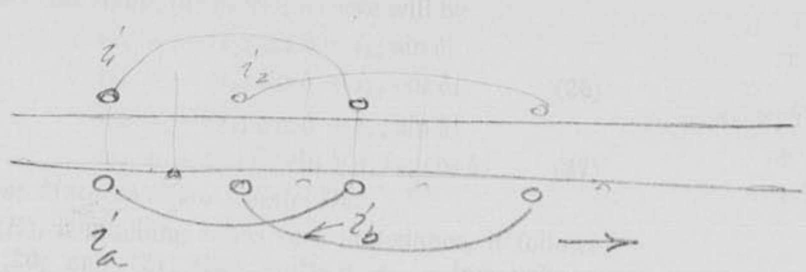
$x_d = x_q$

$$\psi_a = I_d \cos\theta - I_q \cancel{\sin\theta} - \cancel{\frac{x_0}{3}\left(i_a + i_b + i_c\right)} - \frac{x_d + x_q}{3}\left[i_a - \frac{i_b + i_c}{2}\right].$$

$$\psi_a = I_d \cos\theta - I_q \sin\theta - \frac{2x_d}{3}\left[i_a - \frac{i_b + i_c}{2}\right]$$

$$\psi_b = I_d \cos(\theta - 120) - I_q \sin(\theta - 120) - \frac{2x_d}{3}\left[i_b - \frac{i_c + i_a}{2}\right].$$

$$\psi_c = I_d \cos(\theta + 120) - I_q \sin(\theta + 120) - \frac{2x_d}{3}\left[i_c - \frac{i_a + i_b}{2}\right]$$



$$\omega = \frac{d\theta}{dt}, \qquad \theta = \int \omega\, dt.$$

$$e_1 = (r_1 + Lp)i_1' + Mp(i_a' \cos \omega t) + Mp(i_b' \sin \omega t).$$

$$e_2 = (r_2 + Lp)i_2' + Mp(i_b' \cos \omega t) + Mp(i_a' \sin \omega t).$$

$$e_a = (r_a + L_a p)i_a' + Mp(i_1' \cos \omega t) + Mp(i_2' \sin \omega t).$$

$$e_b = (r_b + L_b p)i_b' + Mp(i_2' \cos \omega t) + Mp(i_1' \sin \omega t).$$

Mar. 1, 1930 — H. E. Edgerton

The exponent $\varepsilon^{j\theta}$ can be thought of as an operator which takes into account the speed of the rotor. For instance, in the first ~~of~~ the four equations, the voltages are in terms of drop with respect to the stator current. The current in the rotor of slip frequency for an induction motor in the steady state, is speeded up by a frequency of $(1-s)$ so that its apparent frequency from the stator side is that of the fundamental. Likewise in the expressions for the rotor voltage, the stator currents ~~have~~ their frequency reduced to that of the rotor.

STEADY STATE

BALANCED STATOR AND ROTOR. BAL. VOLTAGE.

With balanced voltage on the stator we know that $E_1 = e_{+1} + e_{-1}$ and $E_2 = -j e_{+1} + j e_{-1}$, or solving for the components.

$e_{+1} = \frac{E_1 + jE_2}{2}$ and $e_{-1} = \frac{E_1 - jE_2}{2}$. Also the rotor will run at a constant speed, i.e. θ has a const. rate of increase.

$\theta = (\omega - n)t$ $\quad n$ = electrical angular velocity of the rotor.

In the steady-state it is known that the current in both the rotor and the stator are sinusoids of frequencies determined by the applied potential E and the slip $\left[s = \frac{(\omega - n)}{\omega}\right]$. Thus the components of current are of the form:

$$i'_{+2} = I_{+2}\,\varepsilon^{j(\omega-n)t} \qquad i'_{-2} = I_{+2}\,\varepsilon^{-j(\omega-n)t}.$$

$$i'_{+1} = I_{+1}\,\varepsilon^{j\omega t} \qquad i'_{-1} = I_{-1}\,\varepsilon^{-j\omega t}$$

When the rotor is shorted $E_{+2} = E_{+1} = 0$.

This in the differential equations for the + components;

$$e_{+1} = \cancel{\frac{E_1}{2}} = z_1 I_{+1}\varepsilon^{j\omega t} + Mp\left(I_{+2}\,\varepsilon^{j\omega t}\right) \qquad z_1 = (r_1 + j\omega L_1)$$

$$e_{-1} = 0 = z_2 I_{+2}\,\varepsilon^{-j(\omega-n)t} + Mp\left(I_{+1}\,\varepsilon^{j(\omega-n)t}\right). \qquad z_2 = (r_2 + j\omega s L_2).$$

cancel exponentials

$$E_1 = z_1 I_{+1} + j\omega M I_{+2}$$

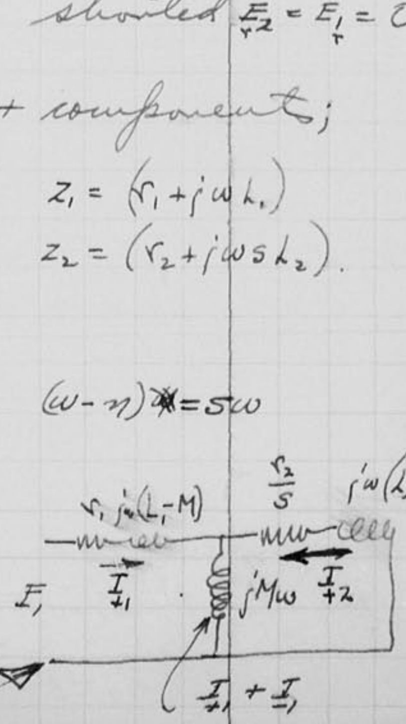
$$0 = z_2 I_{+2} + j\omega M s I_{+1} \qquad s = \frac{(\omega - n)}{\omega} \qquad (\omega - n) = s\omega$$

add and subtract

$$E_1 = \left[r_1 + j\omega(L_1 - M)\right] I_{+1} + j\omega M\left(I_{+2} + I_{+1}\right).$$

$$0 = \left[r_2 + js\omega(L_2 - M)\right] I_{+2} + j\omega M\left(I_{+1} + I_{+2}\right)$$

Which gives the ordinary steady state equations for the ind. motor and the equivalent circuit.



Mar. 1, 1930
H. E. Edgerton

Ind. Motor with 1φ Rotor.

~~As~~ three phase induction motor with a ~~single~~ single phase rotor circuit ~~has~~ has a differential equation that is given by the following component equations. (this is given in Ku's paper A.I.E.E. 1929 Jan-Feb).

$$(r_1 + L_1 p) i'_+ + \frac{M}{2} p\, i'_2\, \varepsilon^{jnt} = v_+ \quad (1)$$

$$(r_1 + L_1 p) i'_- + \frac{M}{2} p\, i'_2\, \varepsilon^{-jnt} = 0 \leftarrow \text{Bal. volts.} \quad (2)$$

$$(r_2 + L_2 p) i'_2 + \frac{3}{2} M p \left(i'_+ \varepsilon^{-jnt} + i'_- \varepsilon^{jnt}\right) = 0. \quad (3).$$

Proceeding as before to pick out the steady state solutions, we select the form of i'_2 since we know that it will be sinusoidal. The magnitude I_2 is undetermined but the frequency is that of the slip.

$$i'_2 = I_2 \left(\frac{\varepsilon^{j\omega t s} + \varepsilon^{-j\omega t s}}{2}\right). \qquad s = \text{slip}.$$

When this is used in (1) it is found that i'_+ must have two frequencies of components, one of rated frequency (that of v_+) and the other of $(1-2s)$ or $(2n-\omega)$.

From (1)

$$\cancel{(r_1 + L_1 p) i'_+ + \frac{M}{2} I_2 \left[j\omega \frac{\varepsilon^{j\omega t s}}{2} - j\frac{\omega}{2} \varepsilon^{-j\omega t s}\right] \varepsilon^{jnt}}$$

$$(r_1 + L_1 p) i'_+ = v_+ - \frac{M}{2} p\, I_2 \left(\frac{\varepsilon^{j(\omega s + n)t} + \varepsilon^{-j(\omega s - n)t}}{2}\right) \qquad \omega - n - n = \omega - 2n \qquad (\omega - n + n) = \omega$$

$$(r_1 + L_1 p) i'_+ = E \varepsilon^{j\omega t} - \frac{M}{4} I_2 \left(j\omega\, \varepsilon^{j\omega t} + j(2n-\omega) \varepsilon^{j(2n-\omega)t}\right)$$

i'_+ is of the form $I_A \varepsilon^{j\omega t} + I_B \varepsilon^{j(2n-\omega)t}$.

Equating each frequency.

$$(r_1 + j\omega L_1) I_A \varepsilon^{j\omega t} = E \varepsilon^{j\omega t} - \frac{M I_2}{4} j\omega\, \varepsilon^{j\omega t}$$

$$(r_1 + j(2n-\omega) I_B\, \varepsilon^{j(2n-\omega)t} = -j(2n-\omega) \frac{M I_2}{4} \varepsilon^{j(2n-\omega)t}.$$

Cancelling exponentials

$$Z_1 I_A = E - j\frac{\omega M}{4} I_2$$

$$Z_{11} I_B = -j(2n-\omega) \frac{M I_2}{4}.$$

In a similiar manner the expressions for the steady state values of i_2 and i_+ can be put into equation (3), thus determining the form of equation that i must have.
From equation (3):

$$(r_2+jswL_2)I_2 + \frac{3}{2}Mp\left[I_A\varepsilon^{jwt-nt} + I_B\varepsilon^{j[(2n-w)t-nt]}\right] + \frac{3}{2}Mp\left[I \quad ? \quad\right] = 0$$

$$I_2[r_2+jwL_2]\varepsilon^{jwst} + I_2(r_2-jwL_2)\varepsilon^{-jwst} + \frac{3}{2}Mjws\,I_A\varepsilon^{j(w-n)t} + \frac{3}{2}M(-jws)I_B\varepsilon^{-j(w-n)t} + \quad ? \quad = 0.$$

$$\underline{i} = I_C\varepsilon^{-jwt} + I_D\varepsilon^{-j(2n-w)t}$$

Separateing the different freq. and cancelling ~~freq.~~ exponentials

$$I_2[r_2+jwL_2]\varepsilon^{jswt} + \frac{3}{2}Mjws\,I_A\varepsilon^{jswt} + \frac{3}{2}jswM\,I_D\varepsilon^{jswt} = 0.$$

and $$I_2[r_2-jwL_2]\varepsilon^{-jswt} - \frac{3}{2}Mjws\,I_B\varepsilon^{-jswt} - \frac{3}{2}jswM\,I_C\varepsilon^{-jswt} = 0$$

$$I_2 Z_2 + jX I_A + jX I_D = 0.$$

I_A see below

$$I_2(Z_2)_c - jXI_B - jXI_C = 0.$$

?

I_B

Equation (2) with known value of i_2 from assumption of the steady state.

$$(r_1+L_1p)\underline{i} + \frac{M}{2}p\frac{I_2}{2}\left(\varepsilon^{jwst-n} + \varepsilon^{-jwst-nt}\right) = 0$$

$$\varepsilon^{j(w-2n)t} \quad \varepsilon^{-jwt}$$

$$(r_1+L_1p)\underline{i} + \frac{MI_2}{4}\left(-jw\varepsilon^{-jwt} - j(2n-w)\varepsilon^{-j(2n-w)t}\right) = 0.$$

$\underline{i}$ must have two frequencies and be of the form.

$$\underline{i} = I_A\varepsilon^{-jwt} + I_B\varepsilon^{-j(2n-w)t}$$ since also $i_+ + \underline{i} = \underline{\text{real}} = i_1$

Equating equal freq. and cancelling exponents.

$$(r_1-jwL_1)I_A - \frac{MI_2}{4}jw = 0$$

$$(r_1-j(2n-w)L_1)I_B - \frac{MI_2}{4}j(2n-w) = 0.$$

Collecting various vector expressions.

$$\mathrm{I}\left\{\begin{aligned} Z_1 I_A &= E - j\omega \frac{M I_2}{4} \\ Z_{11} I_B &= -j \frac{M I_2 (2n-\omega)}{4} \end{aligned}\right.$$

From + sequence

$$\mathrm{II}\left\{\begin{aligned} \cancel{Z_{1c} I_A} &\cancel{= j\omega \frac{M I_2}{4}} \\ \cancel{Z_{11c} I_B} &\cancel{= j(2n-\omega) \frac{M I_2}{4}} \end{aligned}\right.$$

Don't need this.

$$\mathrm{III} \quad Z_2 I_2 + j\frac{3}{2} M\omega s\left[I_A + I_B\right] = 0$$

From I and III.

$$I_2 = \frac{-E\, j\frac{3}{2} M\omega s / Z_1}{\left[Z_2 + \frac{3}{8}\frac{M^2\omega^2 s}{Z_1} + \frac{3}{8}\frac{M^2\omega(2n-\omega)s}{Z_{11}}\right]}$$

$$= \frac{-E\, j\frac{3}{2} M\omega s / Z_1}{Z_2 + \frac{3}{8} M^2\omega^2 s\left[\frac{1}{Z_1} + \frac{2n-\omega}{\omega}\frac{1}{Z_{11}}\right]}$$

$$\frac{2n-\omega}{\omega} = 1-2s$$

since

$$\frac{2n-2\omega+\omega}{\omega} = \frac{\omega}{\omega} - 2\frac{(\omega-n)}{\omega} = 1-2s.$$

$$= \frac{-E\, j\frac{3}{2} M\omega s / Z_1}{Z_2 + \frac{3}{8} M^2\omega^2 s\left[\frac{Z_{11} + (1-2s) Z_1}{Z_1 Z_{11}}\right]}$$

$$\frac{1}{\mathcal{Z}} = \frac{1}{j\left[\frac{2}{3}\frac{Z_1 Z_2}{s\omega M} + \omega M\left[\frac{1}{4} + \frac{1}{4}(1-2s)\frac{Z_1}{Z_{11}}\right]\right]} =$$

$$= \frac{+E}{\mathcal{Z}_2}$$

$$Z_1 = r_1 + j\omega L_1$$

$$Z_{11} = r_1 + j(2n-\omega)L_1$$

$$= r_1 + j\omega L_1(1-2s)$$

$$I_A = \frac{E - j\frac{\omega M}{4}\left(\frac{+E}{\mathcal{Z}_2}\right)}{Z_1} = \frac{E\left(1 \mp j\frac{\omega M}{4\mathcal{Z}_2}\right)}{Z_1} = \frac{E}{\mathcal{Z}_A}$$

$$I_B = -j\frac{M}{4}\frac{(2n-\omega)}{Z_{11}}\left(\frac{+E}{\mathcal{Z}_2}\right) = -j\frac{M}{4}\frac{(1-2s)\omega}{Z_{11}}\frac{E}{\mathcal{Z}_2} = -j\frac{\omega M}{4}\frac{(1-2s)}{Z_{11}\mathcal{Z}_2}E = \frac{E}{\mathcal{Z}_B}$$

$$\mathcal{Z}_A = \frac{Z_1}{1 - j\frac{\omega M}{4\mathcal{Z}_2}}$$

$$\mathcal{Z}_B = \frac{Z_{11}}{-(1-2s)\,j\frac{\omega M}{4\mathcal{Z}_2}} =$$

Mar 2 1930
H. E. Edgerton

Currents in an Ind. Motor with a 1 phase rotor.

In the preceding three pages, I have obtained expressions for the magnitudes (vector) of the current in the rotor and the two components of current in the stator. This ~~is~~ was done by assuming the current in the rotor to be a sinusoidally varying one, the magnitude being unknown. By inspection of the differential equations it was found that two current components must exist in the stator, one of fundamental frequency and one of (1-2S) fund. freq. This was also known experimentally but it could be deduced from the differential equations. Now the various frequencies ~~[illegible]~~ of currents were given unknown magnitudes and placed in the differential equations for the steady state. In this case the p (or $\frac{d}{dt}$) is replaced by the $j\omega$ or $j(2n-\omega)$ for the (1-2S) frequency. In this manner three equations are obtained with three unknowns after the different frequency components are equated and the exponentials cancelled. The three unknowns (I_2, I_A, and I_B) are then solved in terms of

r_1 L_1 r_2 L_2 M S. E.

stator resis. — " inductance — rotor resis — " inductance — mutual — slip — applied stator potential

L_1 = ~~synchronous~~ self inductance of stator per phase. It is the self inductance of one phase (stator), plus the mutual effect of each of the other stator phases.

L_2 = self inductance of the ~~field or~~ rotor.

The current in the rotor is then:

$$i_2' = \frac{I_2}{\cdot}\overset{\cos}{\sin}\,\omega s t = \frac{E}{Z_2}\overset{\cos}{\sin}\, s\omega t \quad \text{where } Z_2 = j\left[\frac{2}{3}\frac{z_1 z_2}{s\omega M} + \omega M\left(\frac{1}{4}+\frac{1}{4}(1-2s)\frac{z_1}{z_{11}}\right)\right]$$

$$z_1 = r_1 + j\omega L_1$$

$$z_2 = r_2 + j\omega L_2 s. \qquad z_{11} = r_1 + j\omega L_1(1-2s).$$

Mar. 10, 1930.

The ~~stator~~ current in phase one is equal to

$$i_1' = i_+' + i_-'$$

$$= 2(I_A \cos \omega t + I_B \cos(2\eta - \omega)t)$$

$$= 2[I_A \cos \omega t + I_B \cos \omega(1-2s)t]$$

$$\frac{(2\eta-\omega)}{\omega}\omega$$

$$\omega\left(-1+\frac{2\eta}{\omega}\right)$$

$$s = \frac{\omega-\eta}{\omega}$$

$$\left(\frac{2\eta - 2\omega + \omega}{\omega}\right)\omega$$

$$= (1-2s)\omega.$$

And the rotor current as demonstrated on the previous page is

$$i_2' = I_2 \cos s\omega t.$$

In these expressions I_2, I_A, and I_B are vectors which are determined by the constants of the motor that is under question. (and the slip).

$$I_2 = \frac{E}{Z_2} \qquad Z_2 = j\left[\frac{2}{3}\frac{z z_2}{s\omega M} + \omega M\left[\frac{1}{4} + \frac{1}{4}(1-2s)\frac{z_1}{z_{11}}\right]\right]$$

$$I_A = \frac{E}{Z_A} \qquad Z_A = \frac{z_1}{1 - j\frac{\omega M}{4 Z_2}}$$

$$I_B = \frac{E}{Z_B} \qquad Z_B = \frac{z_{11}}{-(1-2s)\, j\, \frac{M\omega}{4 Z_2}}$$

Needless to say the above calculations are quite difficult to make since they involve quite a few vector expressions.

Major oral exam in Elect Eng. Apr. 2, 1930 10-200

Notebook # 3

Filming and Separation Record

____ unmounted photograph(s)

____ negative strip(s)

3 unmounted page(s)
(notes, drawings, letters, etc.)

was/were filmed where originally located between page 18 and 19.

Item(s) now housed in accompanying folder.

Equation for torque

$$T = P\,j\,M\left(i'_{a2}\, i'_{b1}\, \varepsilon^{j\theta} - i'_{a1}\, i'_{b2}\, \varepsilon^{j\theta}\right)$$

with the single phase rotor.

$$i'_{b1} + i'_{b2} = I_b \cos s\omega t = I_b\,\frac{\varepsilon^{j\omega t s} + \varepsilon^{-js\omega t}}{2}.$$

$$-j\,i'_{b1} + j\,i'_{b2} = 0$$

$$i'_{b1} = \frac{I_b}{2}\cos s\omega t$$

$$i'_{b2} = \frac{I_b}{2}\cos s\omega t.$$

$(2n-\omega-\omega)+\omega$

$2(n-\omega)$

$\omega - -s2 + \omega$

$\omega - 2s.$

$-j2n + j\omega + j\omega - js$

$-j2(\omega-n) - js.$

$-j2s - js$

$-j3s.$

$$T = jPM\left(i'_{a2}\,\varepsilon^{j\theta} - i'_{a1}\,\varepsilon^{-j\theta}\right)\frac{I_b}{2}\cos s\omega t.$$

$$i'_{a1} = I_A\,\varepsilon^{j\omega t} + I_B\,\varepsilon^{+j(2n-\omega)t}.$$

$$i'_{a2} = I_A\,\varepsilon^{-j\omega t} + I_B\,\varepsilon^{-j(2n-\omega)t}$$

$$\theta = (\omega - s)t$$

$$T = j\,PM\Big(I_A\,\varepsilon^{-j\omega t}\,\varepsilon^{j(\omega-s)t} + I_B\,\varepsilon^{-j(2n-\omega)t}\,\varepsilon^{j(\omega-s)t}$$

$$-\text{conj}\Big)\,\frac{I_b}{2}\cos s\omega t.$$

$$= j\,PM\left(I_A\,\varepsilon^{-jst} + I_B\,\varepsilon^{-j3st}\right)\frac{I_b}{2}\cos s\omega t.$$

$T = \text{real} \times 2$

Used in Apr 21/1930. H.E.E.

PULLING INTO STEP OF A SALIENT-POLE SYNCHRONOUS MOTOR UNDER LIGHT LOAD CONDITIONS.

A salient-pole motor when brought up to speed as an induction motor usually pulls into synchronism and operates as a reluctance motor, if the shaft load is small and other conditions favorable. The salient-poles follow the rotating m.m.f. of the armature by an angle sufficient to supply the load on the shaft. This reluctance torque as a function of the angle is a sin 2θ term. The reason that it depends upon the double angle is because the polarity of the salient poles is not definite but depends upon the position. In other words the salient pole is a mass of iron that endeavors to place itself in a place where the maximum flux will exist and it does not depend on whether the field is north or south.

The synchronous torque expressions for the salient-pole machine as given by Doherty and Nickle at the A.I.E.E. convention in June 1926, are

$$P = \frac{EV\,x_d}{Z^2}\sin\theta + \frac{V^2(x_d - x_q)}{Z^2}\sin 2\theta + \frac{rV}{Z^2}(V - E\cos\theta).$$

The first term ($\sin\theta$) is the synchroniaing power due to the field current. E is the induced e.m.f. in the stator. V is the applied potential. x_d is the reactance in the direct axis. $Z^2 = \cancel{x_d\,x_q}\ r^2 + x_d x_q$ where x_q = the reactance in the quadrature axis and r = the armature resistance.

The second term ($\sin 2\theta$) is the reluctance power. The last term corrects for the losses that exist in the armature. The sum of these components equals the input to the motor.

Before the field current is connected the input to the motor is equal to

$$P = \frac{V^2(x_d - x_q)}{Z^2}\sin 2\theta + \frac{r\,V^2}{Z^2}$$

Core loss has been neglected here. In case measurements can be made then the core loss should be subtracted from P before it is equated to the other quantities.

$$P - (\text{core loss}) = \frac{V^2 (x_d - x_q)}{z^2} \sin 2\theta + \frac{r V^2}{z^2}$$

The shaft load being small (only windage and friction), sin 2 θ will be small and satisfies the equation in four positions for each 360 electrical degrees of displacement. Two of these angles are unstable (90 and 270 degrees) since the slope of the torque curve is negative. The two possible operating angles are 0 and 180 degrees. When the motor pulls into step as a reluctance motor it may be at either of these angles (0 pr 180 degrees.)

Thus when the field is connected to a supply of d-c. there are three possibilities;

(1) the motor will operate at zero angular displacement but with a much smaller armature current.

(2) The motor will operate at 180 degrees of angular displacement but with increased armature current.

(3) The motor will not operate continuously as case (2) if the field current is large enough. In this case the motor must slip a pole, resulting in voilent pulsations of current and power.

The three attached oscillograms were taken for the three cases that are listed above.

December 18th, 1929.

H. E. Edgerton.

Massachusetts Institute of Technolo gy.

Notebook # 3

Filming and Separation Record

____ unmounted photograph(s)

____ negative strip(s)

1 unmounted page(s)
(notes, drawings, letters, etc.)

was/were filmed where originally located between page 20 and 21.

Item(s) now housed in accompanying folder.

Osc. No. 1.

Nov 15

Machine 804 A + B

With only Wind & Friction on set + small machine driving

Watts	V_t	I_a	RPM
1580	220	4.18	1204
1520	218	4.1	1204

With large machine excited for core loss.

Watts input	$V_{t\,804B}$	I_a	$I_{f\,804A}$	RPM	$E_{a\,804A}$
2020	220	5.34	7.3	1210	211
2160	219	5.64	9.2	1208	244
2320	218.5	6.05	10.65	1202	266
2528	217.5	6.70	12.5	1201	287
2980	215.0	7.90	16.0	1196	320

Short circuit on 804 A.

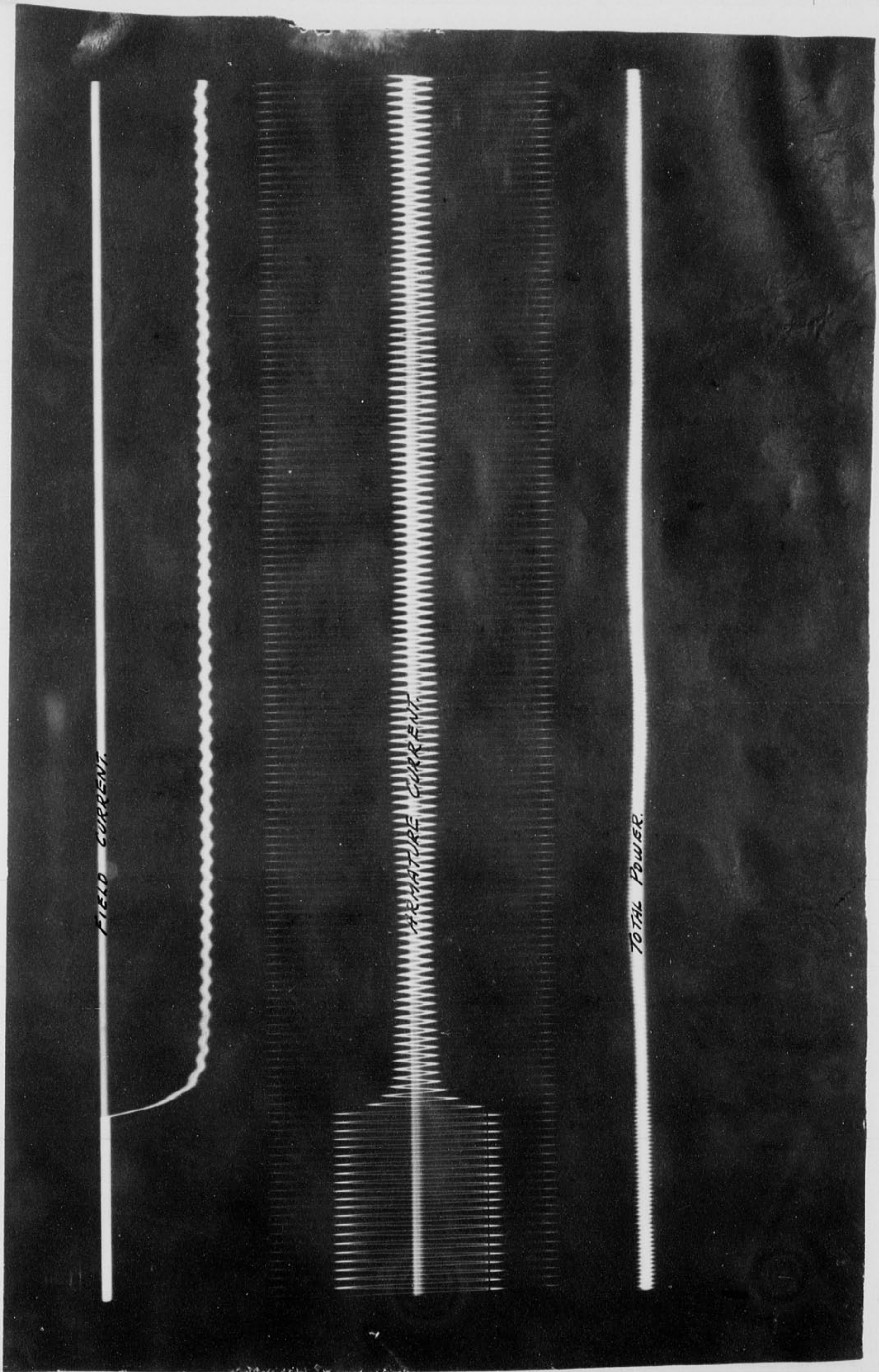
Watts input	$V_{t\,804B}$	$I_{a\,804B}$	$I_{f\,804A}$	Speed	$I_{a\,804A}$
1880	218	5	5.05	1204	76.8
2840	216.8	7.5	9.25	1205	141
2140	217.5	5.65	6.50	1205	99.2
3600	2170	9.6	11.45	1206	174
1440	217.5	3.85	0	1202	—

With added reactance on 804 A & short circuited

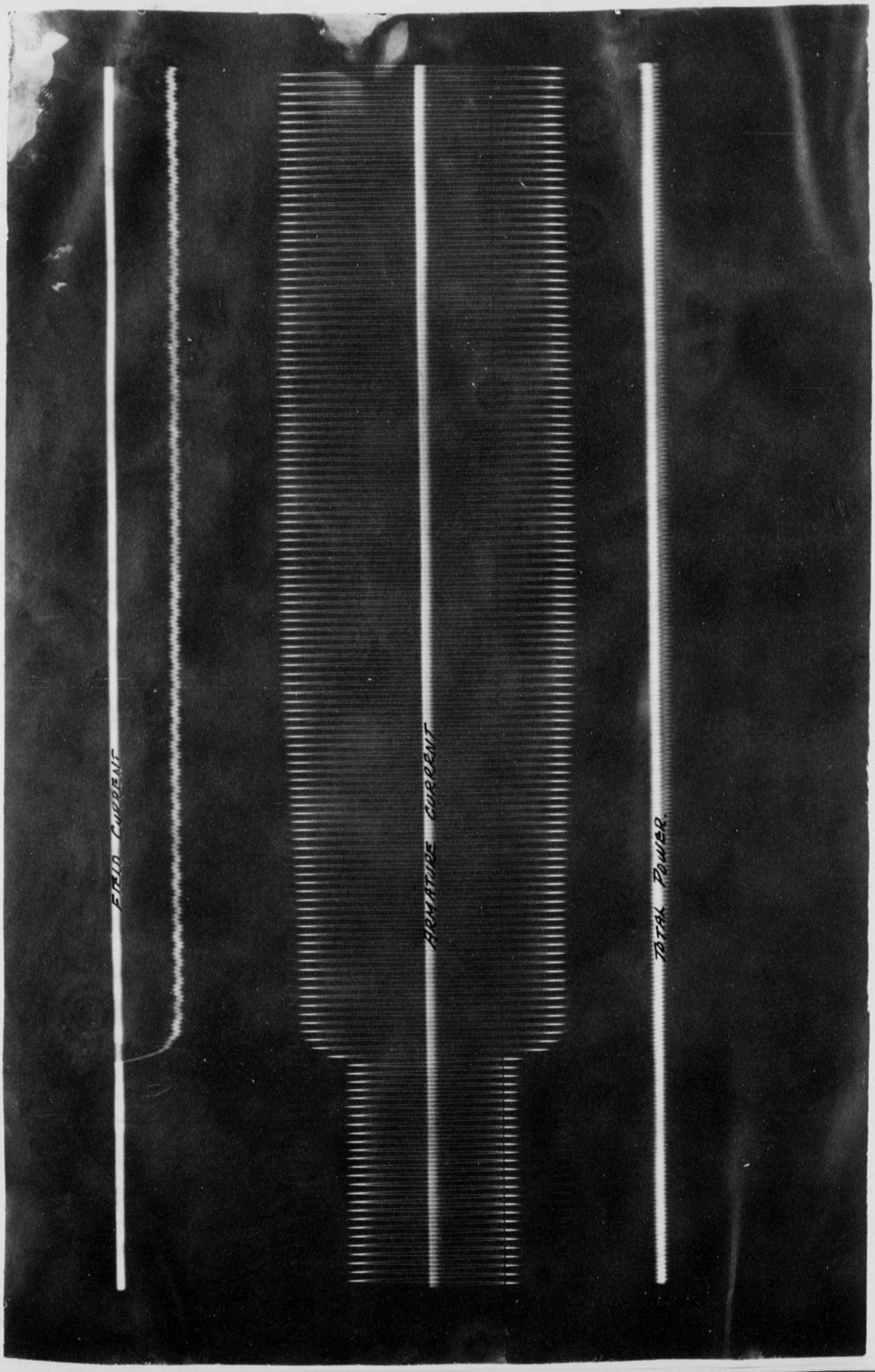
I_f	I_{a_1}	I_{a_2}	I_{a_3}	RPM	E_a to N	X_s	
4.6	22	21.8	21.5	1200	79	3.62	Iron core Reactors
7.7	37	36.5	36.2		129.5	3.54	
10.1	47.6	46.5	46.1		152	3.26	
12.3	55.9	54.3	54.1		167.5	3.06	
4.15	51.2	50.8	49.9		72	1.42	air core reactors
5.20	64	63.7	62.8		89.5	1.41	
6.40	78.4	77.8	77.3		108.5	1.395	

GWB

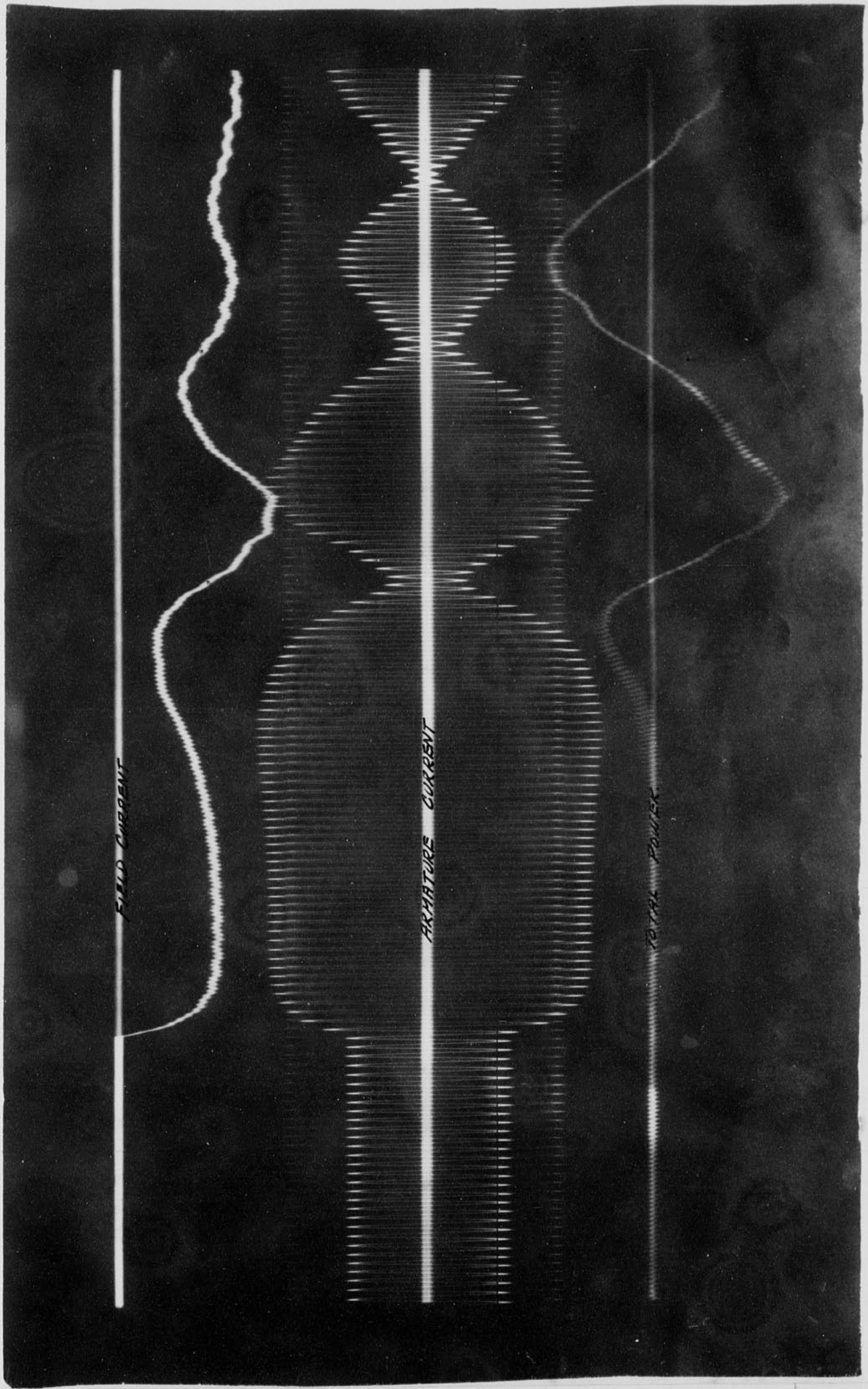
USC. No. 1.



Osc. No. 1.



Osc. No. 2

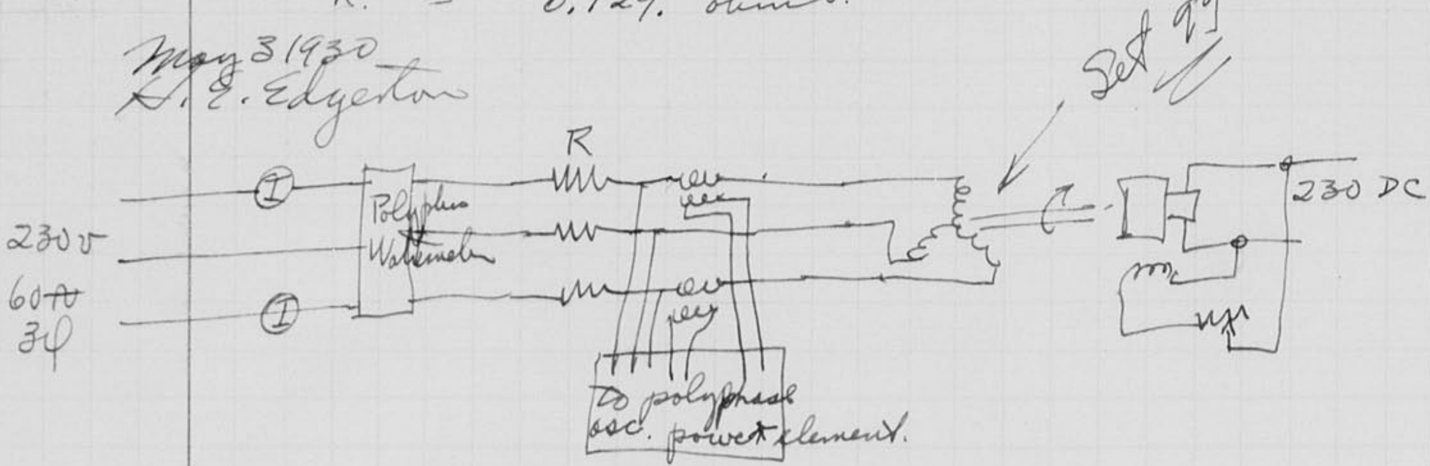


Osc. No. 3.

May 2 1930.
H. E. Edgerton

Resistance of leads for measuring resistance
= ~~0.153~~ ohms. loose contact.
R. = 0.129. ohms.

May 3 1930
H. E. Edgerton



When R was about 0.7 ~~of~~ an ohm the damping was small but still positive.

$R_1 = 1.46 - .13 = 1.33$ ohms.
$R_2 = 1.82 - .13 = 1.69$
$R_3 = 1.62 - .13 = 1.49$

With this resistance the motor has very little damping with E = V. Excitation on fld 1 with 110 volts as source.

Could not show neg power running as ind motor with 1φ rotor.

$R_1 = 3.23 - .13$
$R_2 = 2.88 - .13$
$R_3 = 2.49$

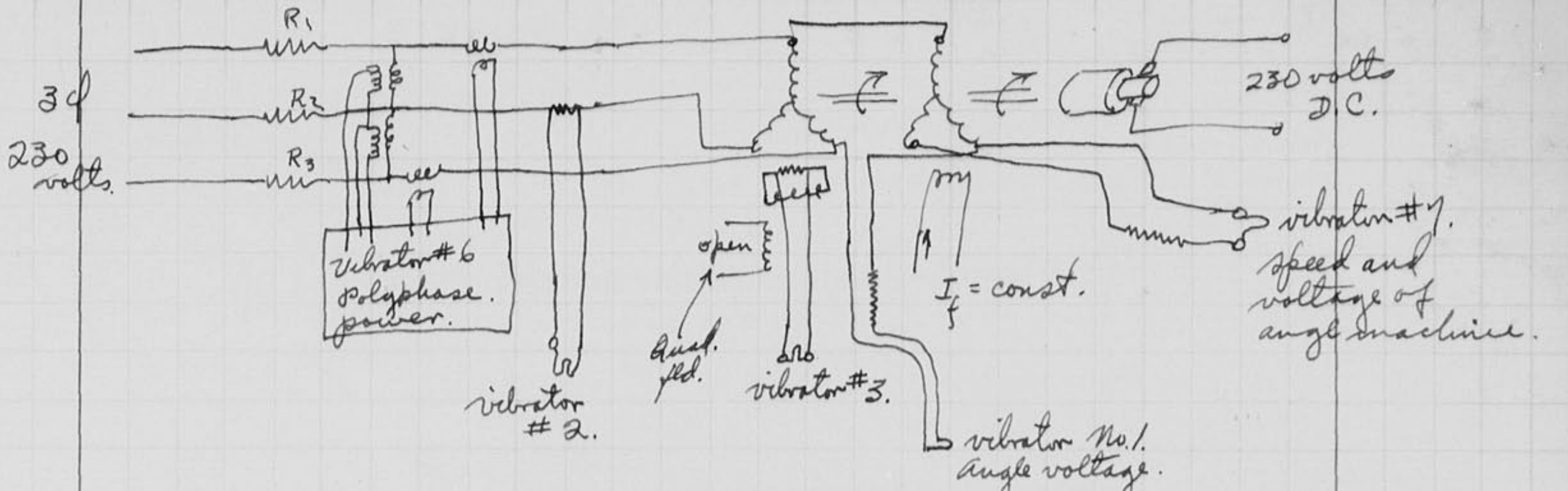
Osc No 7. No excitation 1φ rotor. (Regular field winding short-circuited).
D.C. machine delivering power into lines.
The rotor current vibrator was sticking

Osc No. 8. Repeat. No zeros for V_{angle} and V_{speed}.

Osc No 9. Calib reduced on Vibrator #3 (rotor amps).

Hot. $R_1 = 2.29 - .13 = 2.16$
$R_2 = 2.40 - = 2.27$
$R_3 = 2.32 - = 2.19$
$3 \overline{)6.62}$
2.21 ohms avg.

Set 99



Osc.	H.W	I_1	I_2	V	I_f	E.	
10	547400 x 4	656691	656760	24873		24873	$R_1 R_2$ and R_3 shorted for calib. run.
Calibration	19.2	19.0	20.7	228		252	Fld No 1 (West)

7.68 kw.

Failed to record the zero line of the power.

Same as film No. 9.

Windage Friction (coreloss of 99 A and 99 B).

	x 2					
	5.6	3.±	3±	228	226	Fld No 1 (West).

Osc Self oscillation. Quad fld open.

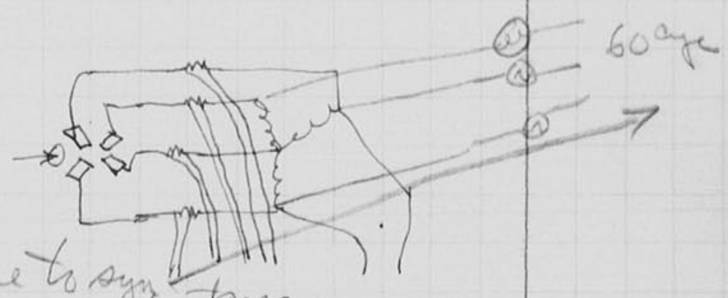
the Power element put ahead of the resistances.

11. 230. zero of P-Power shifted. other calib same.

12. — — — 234 220

1

13 S.S. test on new switch



V	I
98.	~~9.96~~ 9.1

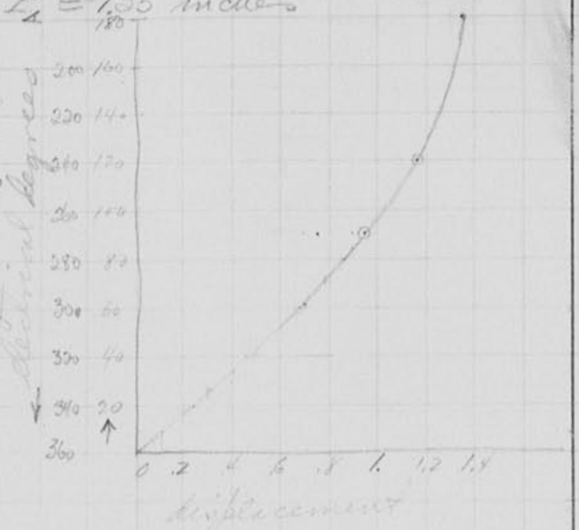
Slow osc. Osc due to syn arrangement, too osc.

14. Same except time delay relay set on fastest point.

Calculation of Oscillograms.

May 4 - 1930
H. E. Edgerton

From film no 9. when θ = 180 electrical degrees
E_L = 1.35 inches



Osc. 11.

P inch	Pos.	E_L inch	P inch	I inch	θ	P KW.	KVA.	11.1
-.39	1	-.23	-.60	.20	-20	-4.61	2.97	3.26
.09	2	+.07	.39	.09	6	-3.0	1.33	1.46
.71	3	.40	+.06	.36	35	+.46	5.35	5.88
1.25	4	.65	+.71	.60	58	5.46	8.92	9.82
1.49	5	.78	1.25	.70	72	9.6	10.4	11.45
1.52	6	.86	1.49	.70	79	11.45	10.40	11.45
1.41	7	.79	1.52	.65	71.	11.7	9.65	10.6
1.15	8	.68	1.41	.53	61	10.8	7.87	8.66
.68	9	.40	1.15	.32	35	8.83	4.75	5.22
.09	10	+.08	.68	.07	7	5.225	1.04	1.15
-.39	11	-.27	+.09	.20	-19	-.692	2.97	3.26
-.60	0	-.45	-.39	.31	-36	-3.0	5.5	6.05

From osc. 10
1 inch of Poly Power
= 7.68 KW.

0.5 inch = 18.8 amp or 7.42 KVA
1 inch = 14.84 KVA.

Calc of Evans and Sels chart.

V = 228
R = 2.21 + 0.33 = 2.54 ohms per phase
X = 4.53 ohms ±
X/X_g = 0.14 x 3
$Z = \sqrt{2.54^2 + 4.53^2}$ = 5.2 ohms.

$P = \frac{V^2 R}{Z^2} = \frac{228^2 \; 2.54}{(1000) \; 27}$ = 4.79 Kw

$Q = \frac{V^2 X}{Z^2} = \frac{228^2 \; 4.53}{27}$ = 8.73 KW.

$R_{ed} = \frac{228 \cdot 230}{5.2 \; 1000}$ = 10.1 kw

6.65
30.35
37.00

Notebook # 3

Filming and Separation Record

____ unmounted photograph(s)

____ negative strip(s)

1 unmounted page(s)
(notes, drawings, letters, etc.)

was/were filmed where originally located between page 26 and 27.

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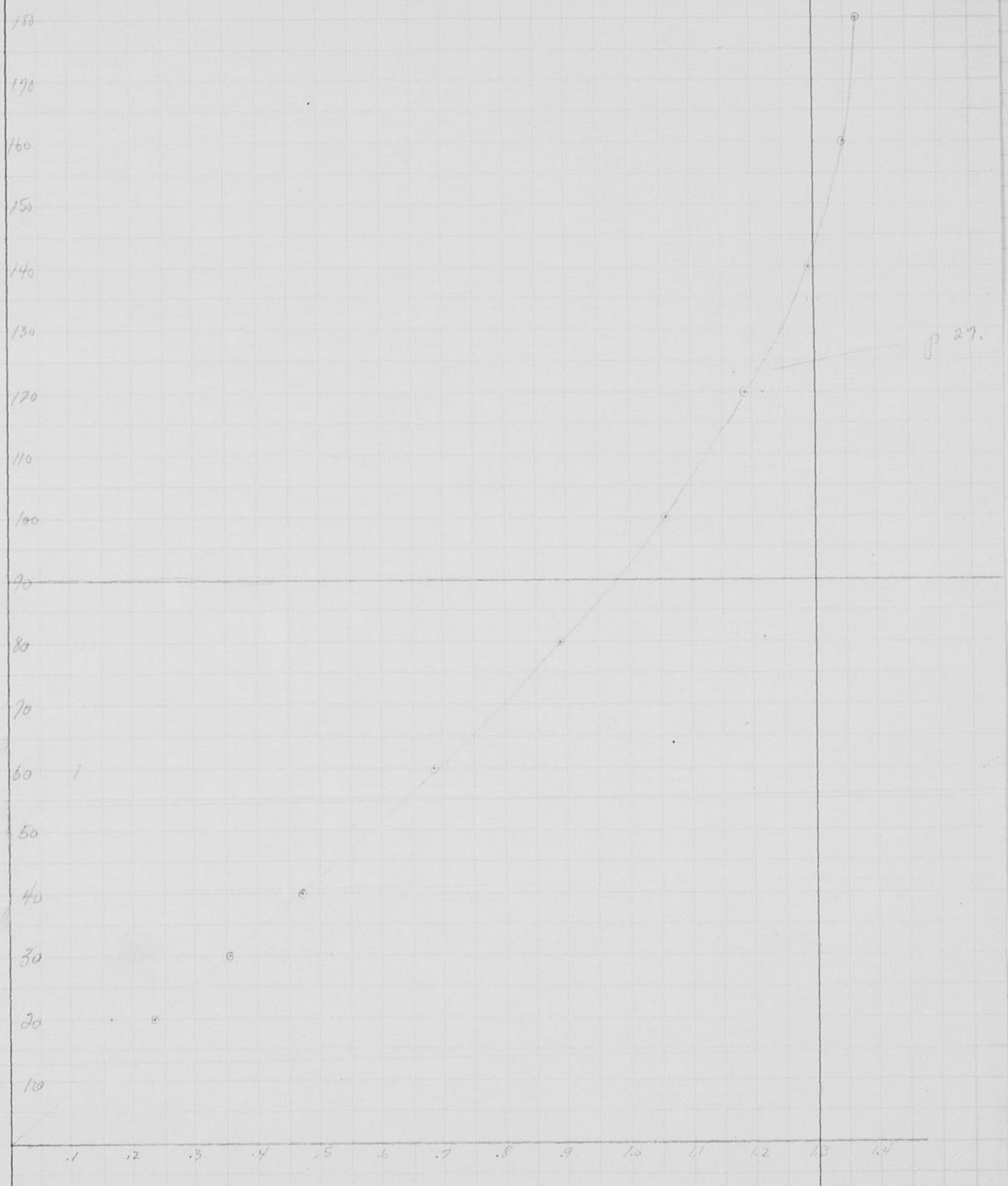

180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
.1
.2
.3
.4
.5
.6
.7
.8
.9
1.0
1.1
1.2
1.3
1.4
p 27.

Calculation of Oscillogram No. 9.

May 4 1930
H. E. Edgerton

No.	angle volts inches	θ deg ✓	P inch	P kw ✓
1	1.32	+147	.20	1.53
2	1.22	124	.35	2.69
3	1.1	107	.55	4.22
4	.97	88	.66	5.07
5	.82	72	.53	4.07
6	.61	52	.21	1.61
7	.41	35	−.03	−.23
8	.22	18	−.16	−1.23
9	.00	00	−.12	−0.922
10	.24	21	+.03	+.23
11	.42	36	.18	1.38
12	.60	51	.33	2.54
13	.79	69	.54	4.15
14	.97	88	.69	5.30
15	1.10	107	.57	4.38
16	1.20	122	.32	2.46
17	1.29	140	.05	.384
18	1.35	161	−.13	−1.0
19	1.37	180	−.15	−1.15
20	1.35	161	−.02	−.154
21	1.32	147	+.16	+1.23
22	1.25	130	.30	2.3
23	1.15	114	.53	3.84
24	1.02	94	.66	5.07
25	.85	75	.58	4.45

Calc of slip,

180 degrees + 15 cycles of time

$\frac{d\theta}{dt} = \frac{180}{.25} = 720$ elec'l deg/sec.

$\omega = 360 \times 60 =$ syn speed in elec deg/sec $= 21,600.$ elec deg/sec.

$s = \frac{\frac{d\theta}{dt}}{\omega} = \frac{720}{21600} = 3.33$ percent slip.

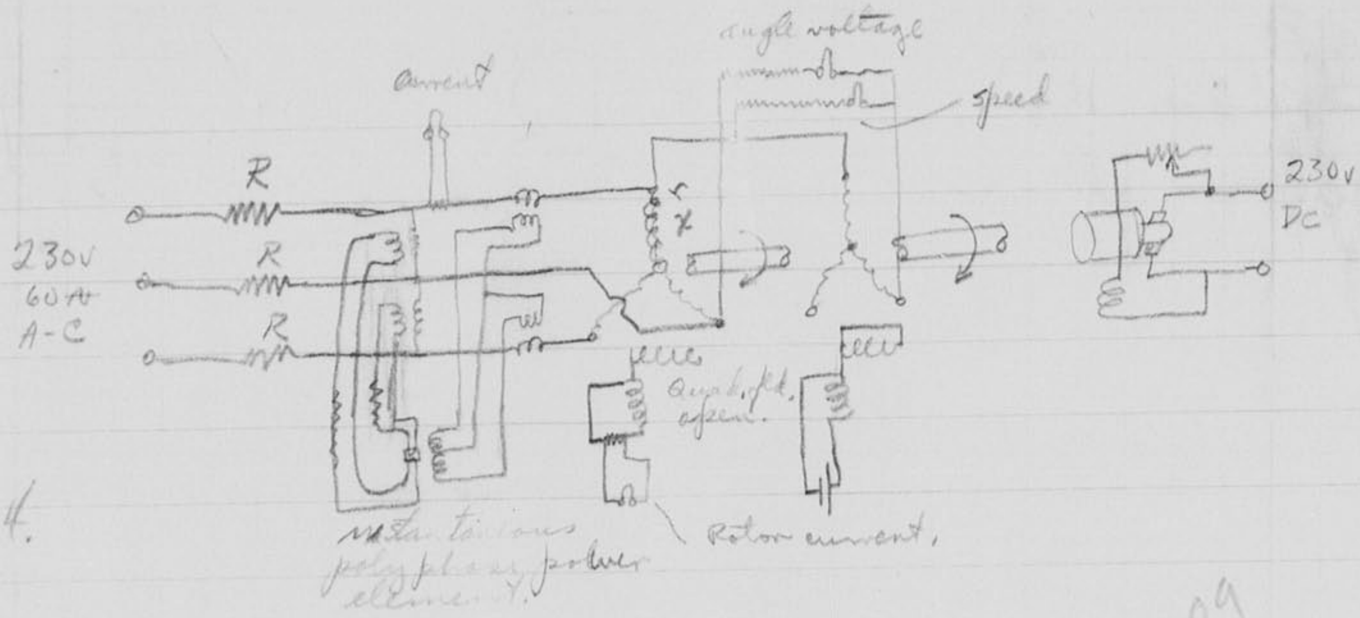
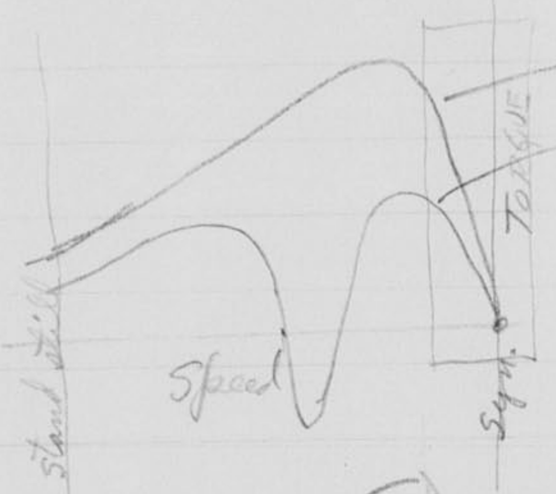


Fig 4.

wiring diagram for oscillogram no 7 8 9 ?

Fig 1.

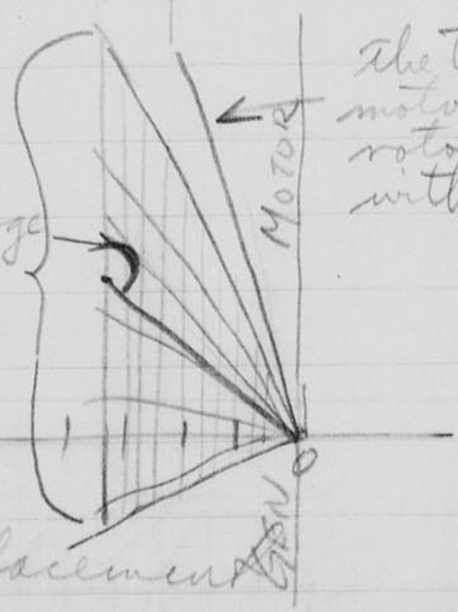


polyphase rotor winding

single phase rotor winding (average torque curve. the instantaneous torque varies at double slip frequency).

Fig 2.

The average torque from a motor with a single phase rotor varies as a function of angular displacement (see fig 3)



the torque from a motor with a polyphase rotor does not vary with angular displacement.

Fig 3. θ-Power.
Fig 5 osc.

Notebook # 3

Filming and Separation Record

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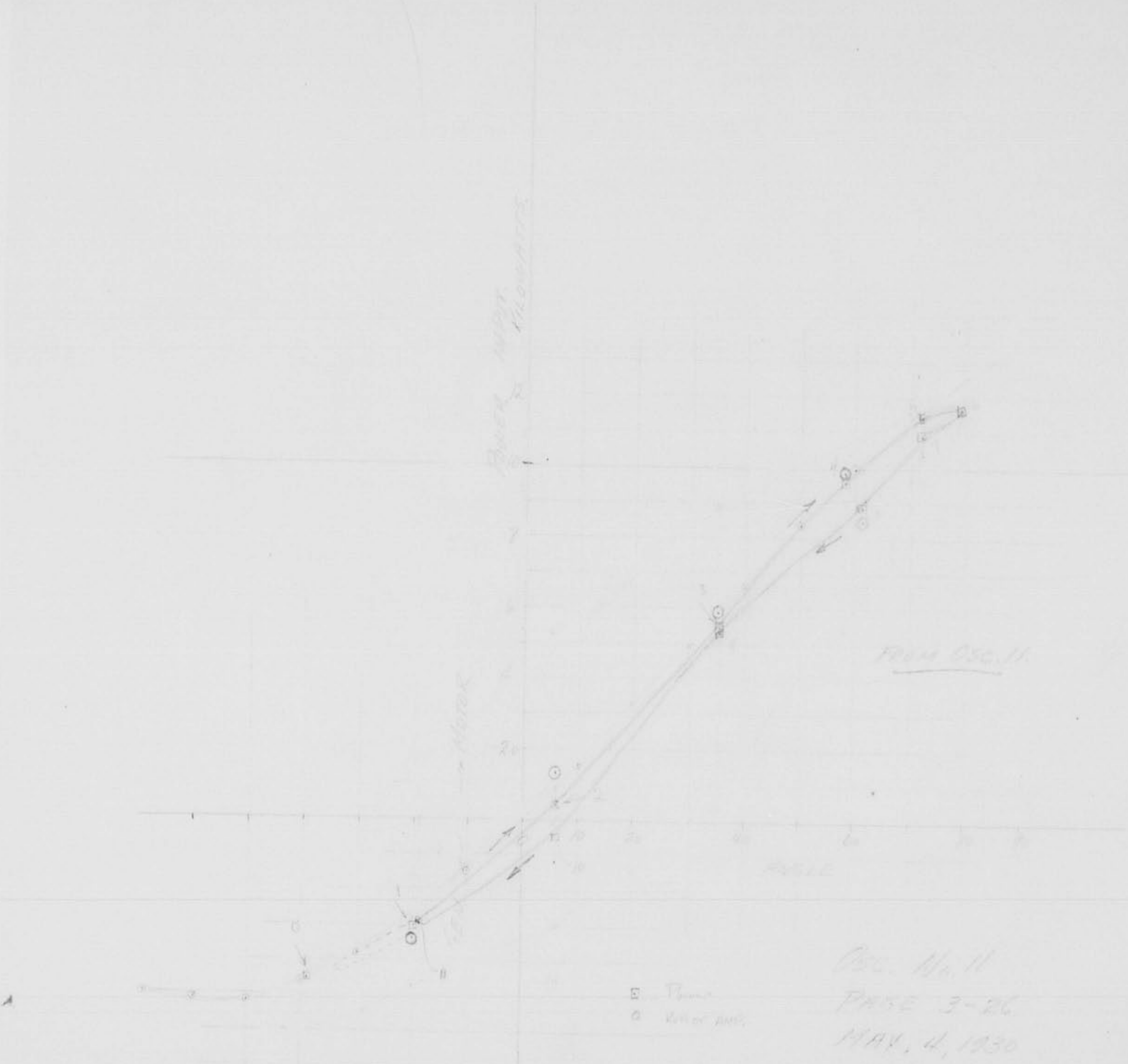


OSC. No. 11
PAGE 3-26
MAY, 11, 1930
H.E. EDGERTON

OSC. NO. 11.
PAGE 3-26
MAY 4, 1930
H.E. EDGERTON

Self-Oscillation of 96.

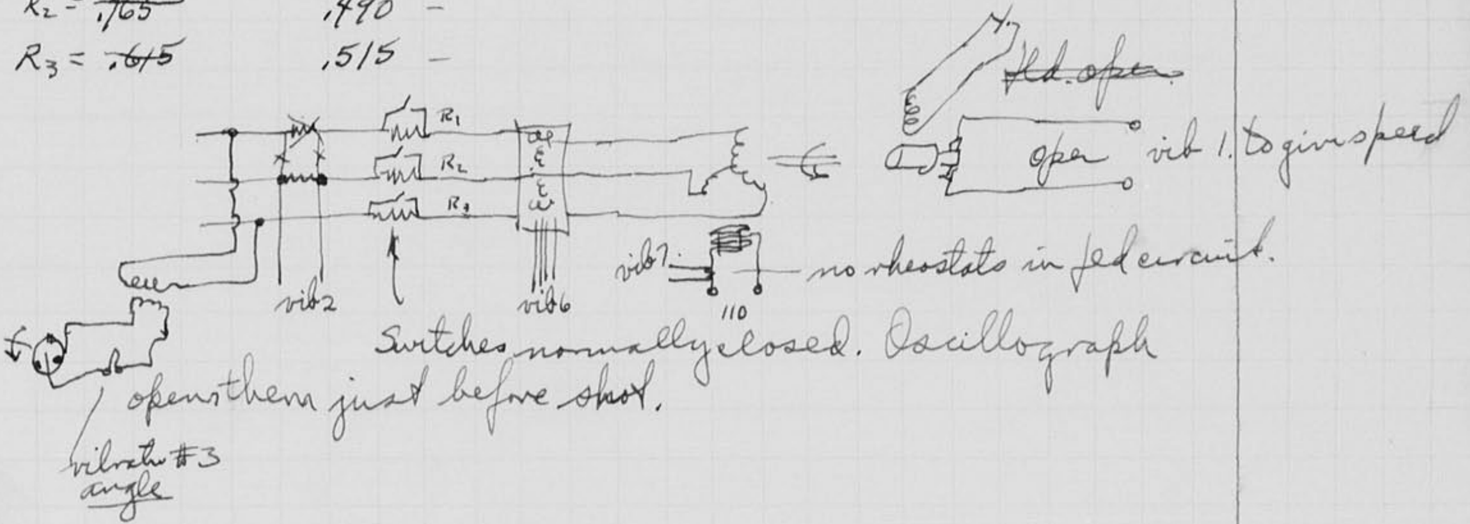
May 6 1930
H. E. Edgerton
John Ross.

Salient pole syn. motor # 305997.
G.E Co ATB-6-37.5-1200 Form PB
Pf-80 3ϕ 90-180 amps 30 KW. 60~. ~~37.5~~
Direct Connected to.
1016477 Shunt type RC B3 A form
230 volts amps 160 1200 R.P.M.

lead resistance.

R_1 = ~~.507 - .128~~ .466 - .128
R_2 = ~~.765~~ .490 -
R_3 = ~~.615~~ .515 -

Osc. 15



Switches normally closed. Oscillograph opens them just before shot.

16

17

18

19. Calibration

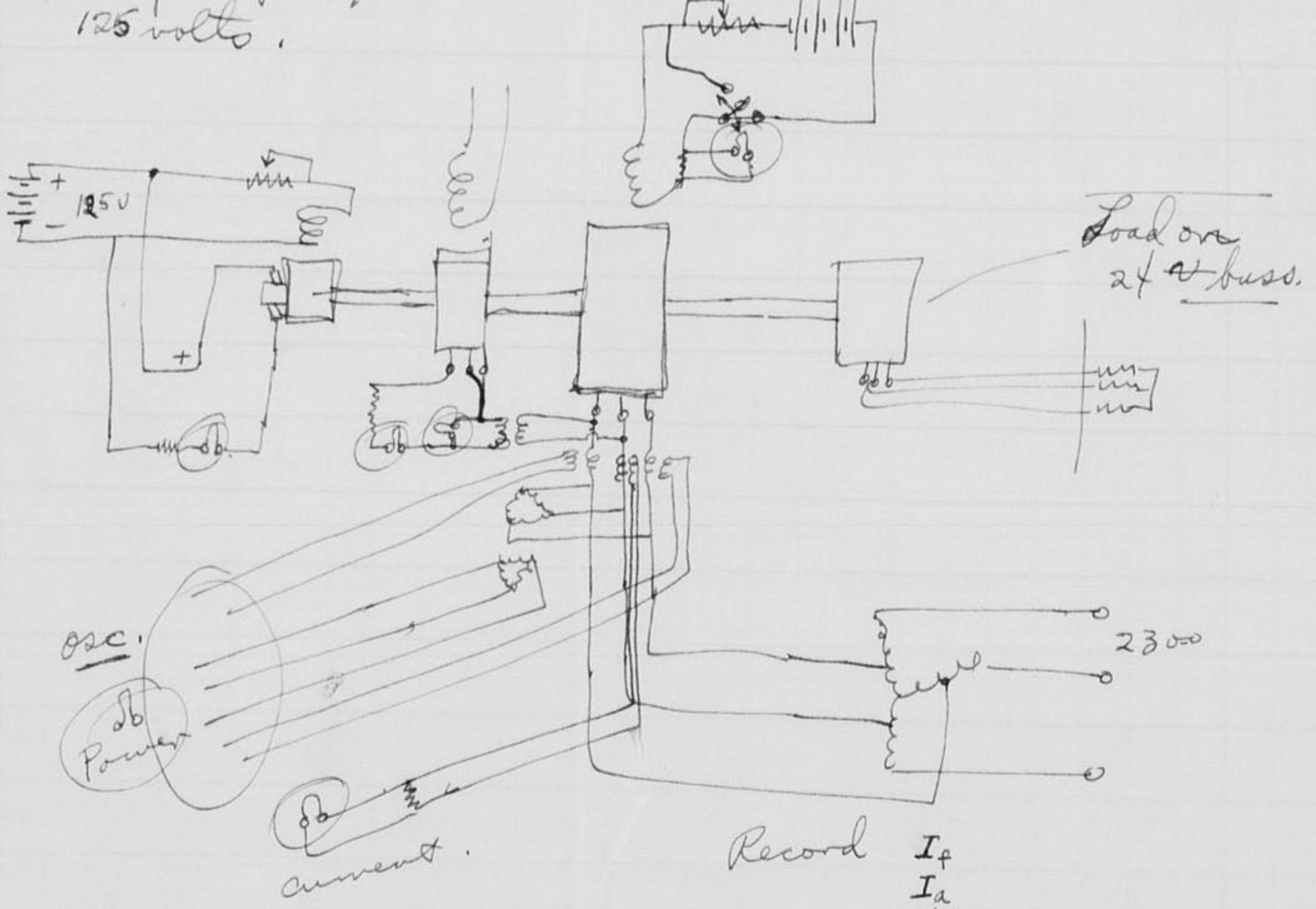
I	V	W	I_f on 230 v.		Dc motor I_f	E	I
50.3	221	×20 ~~.246~~ .981	2.82		2.22	228	69.0

Salient-Pole Motor
Outline of Pullin tests

May 12, 1930
H. E. Edgerton

G.E.	G.E.	G.E.
A.C. Generator.	Synchronous Motor.	A.C. Generator
#842053	# 302707.	# 842052
ATI-10-62.5M 720 C	ATI-10-160M 720	ATI-4-62.5-M-720 C
50KW 720 p.f. .8	40 amp 2300 v 60~	50KW speed 720 p.f. = .8.
157 amp volts 230.	H.P. output 160 speed 720	amp 157. Volts 230.
	P.f. = .8	
	125KVA.	

G. E.
D-C Exciter
502320
type FF-4-5-720 form E
40 amp speed 720.
125 volts.



Record
I_f
I_a
V_a
V_{angle}.
P_{input}.
Speed.

110vac for motor.

DC 220v for arc and relay.

40
10,000 / 240 100 x 1. = 100 voltamp.

May. 14, 1930
H. Edgerton

WR^2 from ~~Ira~~ A. Terry's letter of May 5, 1930. and reactances.

#	WR^2	x_d	x_q
# 842053	960	.362	0.173 .173.
# 302707	1175	.651	.32
# 842052	627	0.409	0.209
total WR^2	2762 pound feet squared.		

$$P_j = \frac{18.6\ WR^2 f}{p^2} \times 10^{-6} = \frac{18.6\ \ 2762\ \ 60}{10 \times 10} \times 10^{-6} = 0.0308 \text{ kw/elect deg/sec}^2$$

Reluctance power at $\frac{1}{2}$ voltage.

$V = .5$

$x_d = .651 \quad x_q = .32$

$$P = \frac{V^2(x_d - x_q)}{2\, x_d x_q} = \frac{.5^2(.651 - .32)}{2\ .651\ .32} = 0.198$$

$$P_{KW} = \cancel{160}^{125}\ .198 = \cancel{32}\ \cancel{8} \text{ KW}. \quad 25. \text{ KW}$$

$160\ .198 = 31.8$ KW.

Synchronous power.

$$P_m = \left(\frac{VE\ \cancel{x_q}}{\cancel{x_d x_q}}\right) \cancel{160}^{125} = \left(\frac{.5\ \ .5}{.651}\right) \cancel{160}^{125} = \cancel{125}\ 61.3\ \ 48.0 \text{ KW} \quad \cancel{31.3} \text{ KW}. \quad 61.5 \text{ KW}$$

160 160

1100 volts - 8.8 amps field current. from sat. curve.

$$\frac{31.3 \text{ KW} \times 1.000}{\sqrt{3}\ \ 1.100} = 16.4$$ amperes required from a.c. 1100 volt source.

The motor requires 160 amps. exciting current.

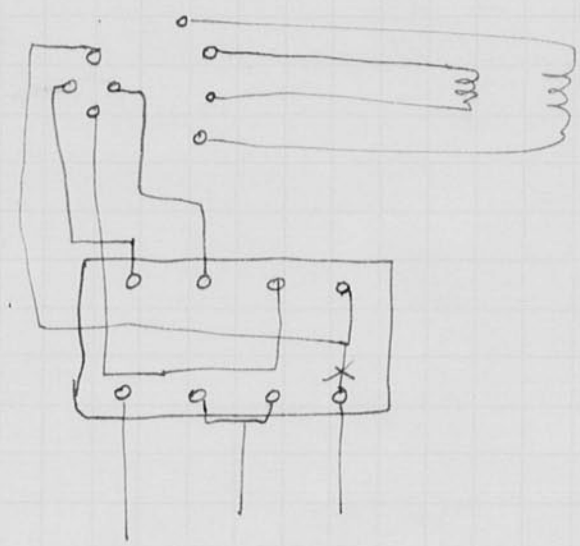
May 15, 1930
A.E. Edgerton
Fritz Brodevick

Test on 302707.

C.T. 40:1
C.T. ~~200~~:1 ratio
P.T. 20:1.

V. 55 on start   111 — 115+ start.
58 on run.
I less than 1 amp run.
3 amps on start. $\frac{40}{}$ $\frac{120}{}$
32. = 1.6 amp × ~~100~~ 20 running light.
.32. amps.

Connections of polyphase watt element of oscillograph



Field Resistance.   9.5 ohms fld + Rheo on board.
5.2 ohms fld only with Rheo out.

$$S \leqq \frac{600 \pm}{n} \sqrt{\frac{P_m}{f\,(WR^2)}} \qquad n \text{ syn speed.}$$

$P_m = 50$
$f = 60$
$WR^2 = 2762$
$n = 720$

$$S < \frac{6}{720}\sqrt{\frac{50}{60 \quad 2762}} < 1.45\%$$

61.5

see page 37 for corrected.

Steady-State Power-Angle Curves on #302707.

May 16 1930.
H. E. Edgerton.
Paul Fourmarier.
Sam Levine
Chas Kingsley.

θ	V_1 A.Cline	V_2 Gen	Gauge 32270.	V_1 X20 24873.	KW × X10 X 20	I_1 X10	I_2 X10	I_f D.	P_{out} KW meter on board.	V	
	116.5	116.5	59.0 .253 14.7 29.4	115.3	1.7 34.	1.08	1.05	18.9	24	130.	
			56.5 .242 14.1 28.2	115.0	2.28 45.6	1.34	1.33	18.8	34	155	
			56.0 .240 13.9 27.8	115	2.44 48.8	1.43	1.42	18.95	38	164	
			53.9 .2315 13.4 26.8	115.3	2.85 57.0	1.61	1.6	18.8	46.	180	
			61.0 .262 15.2 30.4	115.2	1.37 27.4	1.—	.95—	18.8	18.	112.	
			64.3 .276 16.0 32.0	115.2	.90 18.0	.75	.75±	18.8	8.0	70	
$2\sin^{-1}\frac{66.5}{233.0} = 16.54^\circ \times 2 = 33.08^\circ$ (.285)			66.0 .283 16.45 32.9	115.2	~~.40~~ 8.0	.65	~~.65~~	18.9	0	0	
			66.5 .285 33.08	115.2	~~.5~~ .47 $\boxed{9.4\text{ Kw}}$	—	—	18.9	0	220	core loss of 24
			52. .223 12.9 25.8	115.0	3.46 69.2	1.86	1.88	18.9	57	230.	
			50. .215 12.4 24.8	115.0	3.92 78.4	2.1	2.1	18.9	66	250.	
			66.5	115.2	,5	3.46	3.46	9.2	0	0	
			64.0	115.0	1.18	3.5	3.51	9.25	9.0	97	
shut down			60.0	115.3	1.61	3.55	3.56	9.25	20.4	138	
			56.	115.0	2.06	3.71	3.70	9.20	28.5	166.	
			54.5	115.0	2.30	3.77	3.74	9.20	33.2	176	
			52.5	115.0	2.64	3.84	3.82	9.20	39.5	192.	
			49.5	115.0	3.17	3.97	3.95	9.20	49.0	213	
meters interchanged			47.5 ↔	115.0	3.47	4.07	4.07	9.2	55.0	227	
			45.5	116.0	3.82	4.18	4.20.	9.1	60.	239	
			43.0	115.8	4.17	4.33	4.33.	9.1	66.5	252	

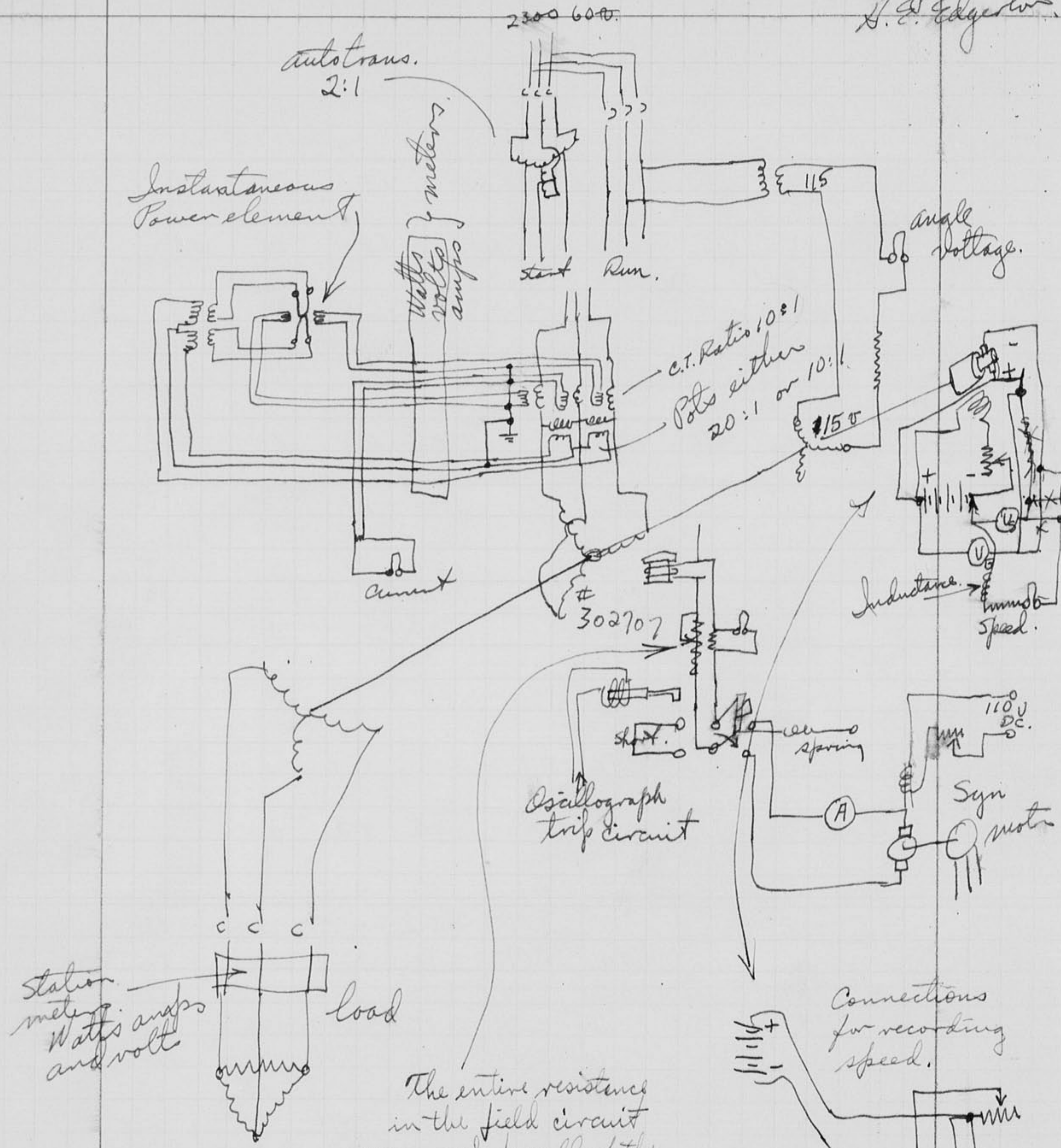
1/2 volts on autotrans

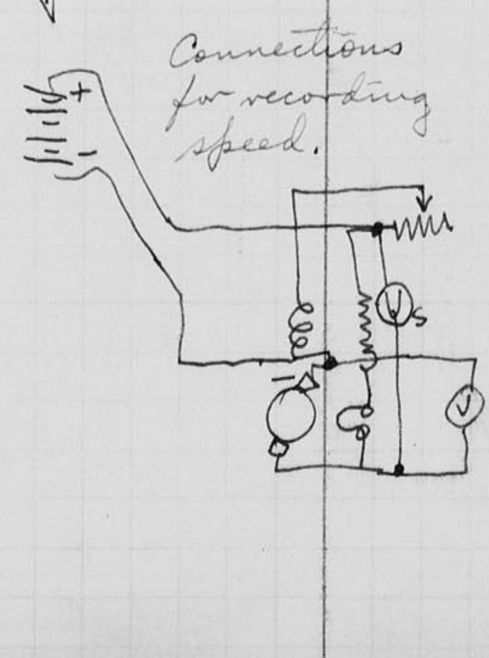
3.2? guess from yesterdays tests

shorted thru 5 ohms

32. → 16. } Reluctance pullout / Pullin.

May 17 1930
H. E. Edgerton.





The entire resistance in the field circuit was used for all of the tests. This resistance is the one on the control panel.

Pulling-into Step Oscillograms on # 302707.

and. Sliptorque Curve of 302707.

H. E. Edgerton
May 17, 1930

Kingsley Jr.
Paul Tournmarie
G. Levine

Vangle machine			V ×10	I ×10	HW ×10×10	I_f	V_B	V_s max min.	P_{out}	V_{out}	
			115	3.03	.80	0		.22 .33	0		
				5.+	3.– 4.7			.1 – .3	25	175.	
			114	5.+	1.3 – 4.0				18	148.	
		Osc 20. slip avg.		1.71	3.4	9.3			25.5	175	
		21.	115	1.69	3.3	9.4			25	173	
		22	115	1.82	3.61	9.4			27.5	182	
slip from angle curve	1.5 1.49	23 68" 66 67	115	1.84	3.61	9.2			27.5	157	0 ohms in series with V_s
		24		Off scale – failed to pull in					27.5	155	2 Ω in series with V_s.
1.47	off.	25	(trip out too soon)						27.3	152	
			114.5	1.84	3.7	9.2		19.8			
1.54	1.49" 1.585%	26 66 1.515	115	1.86	3.69	9.2		19.8	27.8	154	
1.49	1.40" 1.49%	27 66 1.515	115	1.84	3.67	9.25		19.8	27.7	153	
1.73	1.61" 1.71%	28 1.54	115	1.86	3.72	9.55		19.8	28.2	155	
1.49	1.42" 1.51%	29	115	1.86	3.66	9.4		19.8	27.8	153	
		30	115	2.11	3.98	8.55	.2v 19.5v R	24.5v angle speed	31.0	161	calibration

These readings were made immediately after synchronization.

Slip of film 30 $\frac{\ldots 0.2}{19.5}$ = 1.025%. = $\frac{(1.07 \text{ to } .80)}{2}$ inches variation .94± in.

Calculation of slip from number of cycles per 360 elect degrees

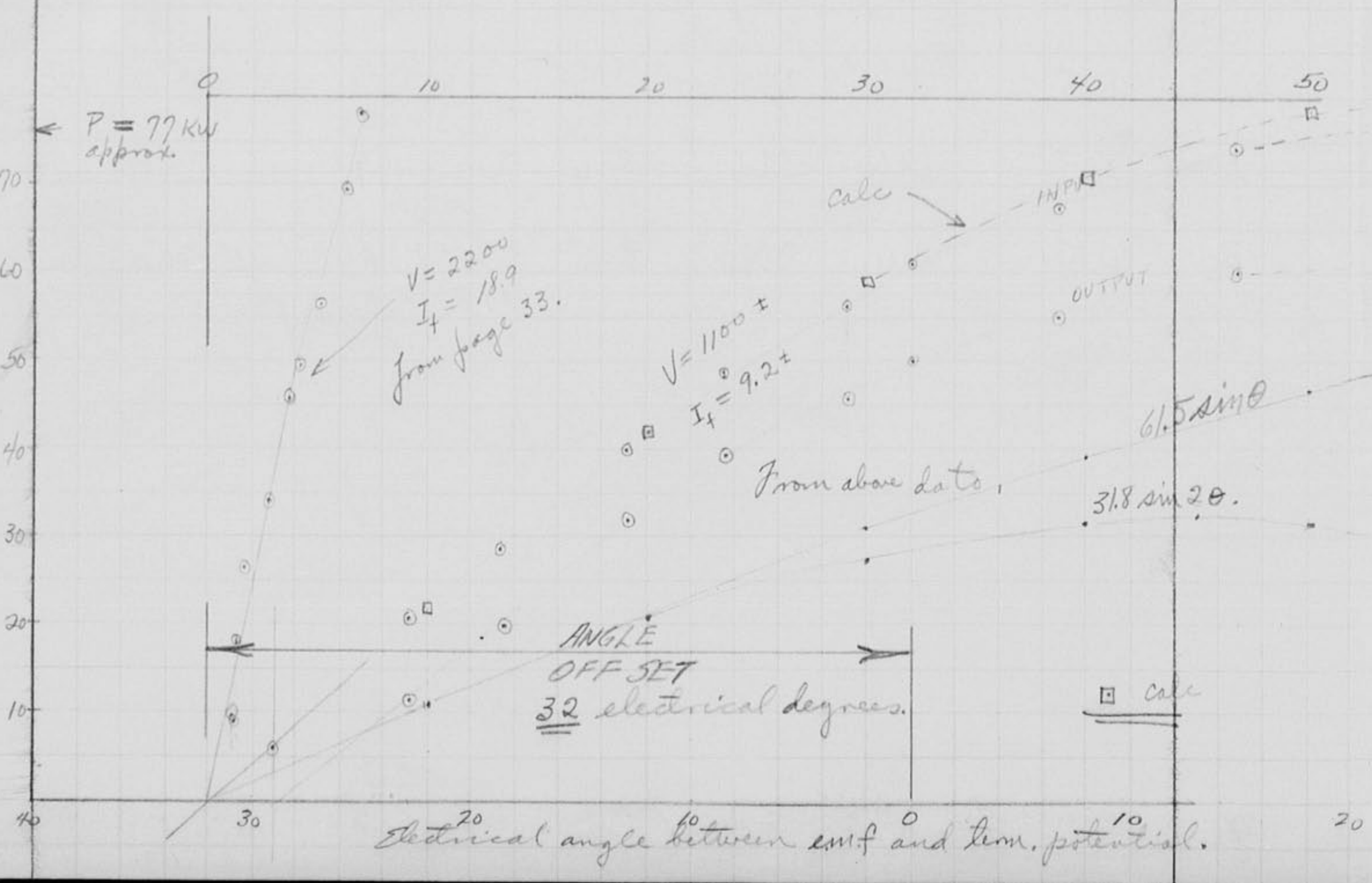
x cycles / elect rev.

slip = $\frac{60}{x}$ cycles/sec % slip = $\frac{60 \times 100}{60x} = \frac{1}{x} \times 100$

Steady-state,

May 17, 1930. Power-Angle Curve 302707

V_{ac} ×10	i_{ac} ×10	i_{ac} ×10	kW ×10×10	$V_{avg.}$	P_{out}	V_{out}	i_f	$\frac{V_{avg}}{2 \times 116.5}$	θ	θ −32
115.2	–	–	0.61	59.	0	0	9.2	.253	14.55	29.1
115.5	1.05	1.02	2.05	46	12	105	9.1	.197	11.35	22.7
115.1	1.46	1.44	2.82	38	20	132	9.1	.163	9.39	18.78
114.9	2.03	2.05	4.00	26	32	161	9.2	.111	6.4	12.8
114.6	2.53	2.56	4.87	17	39	181	9.2	.0729	4.18	8.36
115.0	3.04	3.02	5.65	6±	46	196	9.2	.0256	1.45	2.90
114.2	3.33	3.32	6.15	0±	50	205	9.15	0	0	0
114.3	3.74	3.75	6.72	13	55	215	9.2	.0557	3.2	6.4
114.2	4.40	4.42	7.40	30	60	225	9.±	.129	7.35	14.7



Probability of Synchronization

May 17 1930.

V	I_f	P output at syn speed.	V. output.	x = synchronized o - failed.
115	9.2	24.5	143	X X

Discontinued due to lateness of hour.

From page 31,

Calculated $P_{reluctance}$ = 31.8

" $P_{syn.}$ = 61.5.

Condition for limiting slip

$$s \leq \frac{600}{720}\sqrt{\frac{61.5}{60\ 2762}}$$

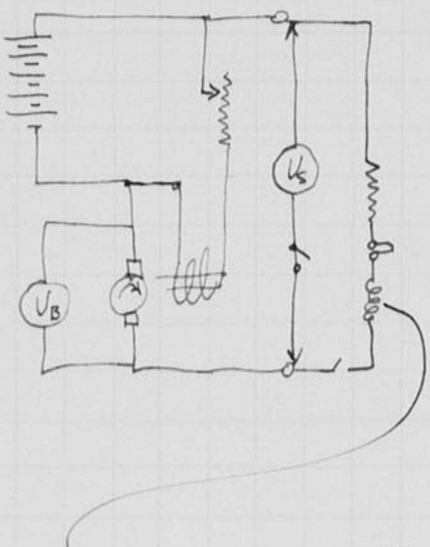
.0163705
.01925

$$\leq .0160$$ or <u>1.6 percent slip.</u>

2000) 1.000

Calibration of speed vibrator

May 19, 1930.
H. E. Edgerton
Paul Bourmarier



V_B	V_s	Def in inches.	Slip	slip/inch
19.4	.20	.96		
19.4	.30	1.31		
19.4	.30	1.22		
19.4	.20	.80	after the commutator was cleaned.	
	.32	2.03		

(220 volts
.3 amps ±
60 cycles.)
Less than .5 of an amp.

These show that the speed cannot be calibrated by this means.

With 1/3 of inductance 220 v 3.0 amps 60 ~.

Average slip may be computed from the angle voltage. Then this should give the average of the speed record. It also may be computed from the record of field current since the fundamental of this is at slip frequency.

There was too much inductance in series with the speed vibrator for the tests taken on the 17 th. However the records show the tendency of the speed which is important and sufficient for us.

Synchronization Tests #302707

May 19, 1930
A. E. Edgerton
Paul Fourmaier.

V	I_f	HW output	I_a	P	V.
x10 ✓	✓	x10 x10	x10	output	out.
	9.2-			28.-	0

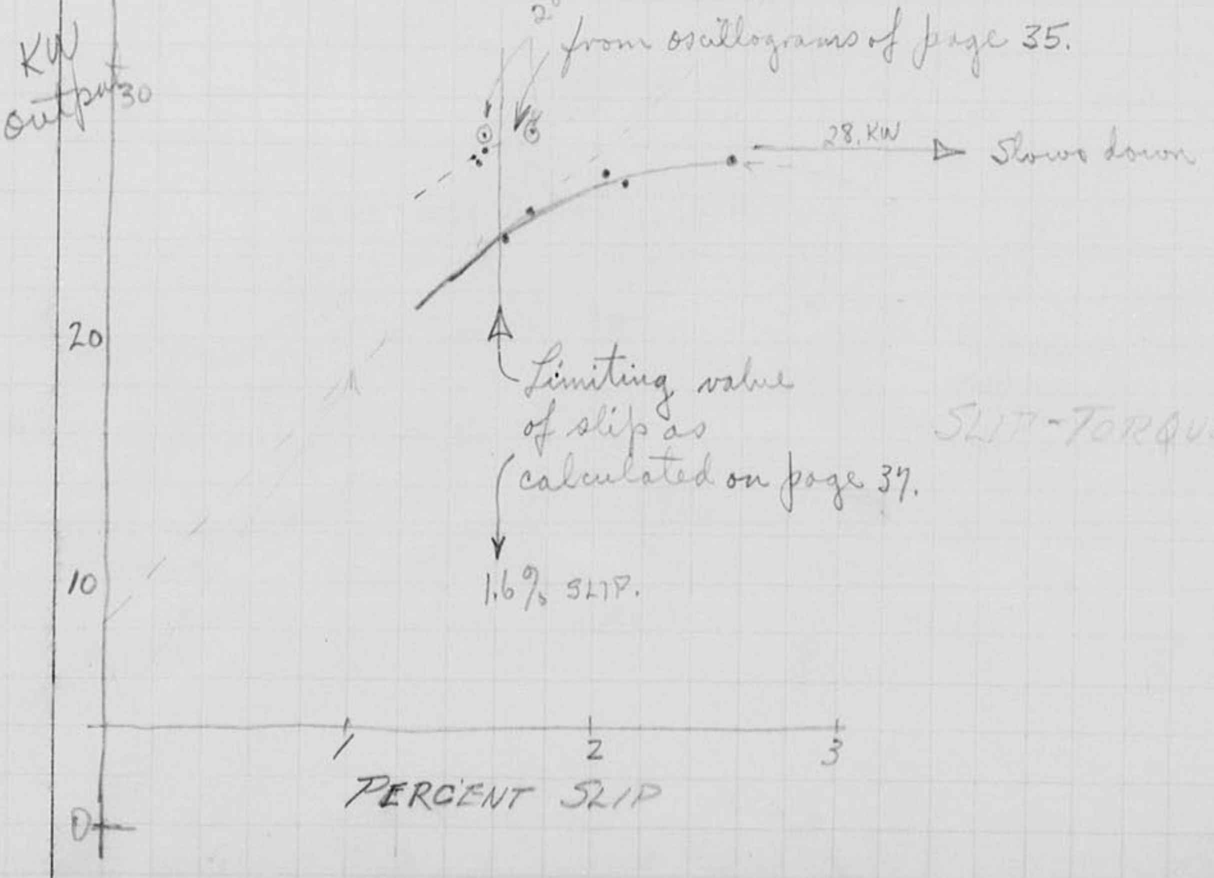
x = Syn.   0 = did not syn.

A load of 28 KW causes the slip to be much larger than it was ~~yesterday~~ Sat.

		slip %		
	29 beats in 1/2 min.	1.61	24.1	158
113.6	31 "	1.724	25.3	164.5
113.6	38 ..	2.11	26.5	171.0
113.5	46	2.56	27.6	176.0
	37 .32-volts / 194	1.65 / 2.05	26.5	170.0 ±

$\% \text{ Slip} = \frac{\text{beats}}{36.00} \%$

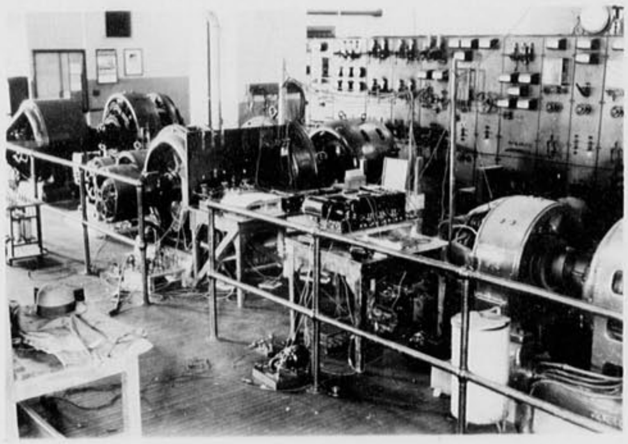
with fld shorted the motor pulls out at 26.5 kw.



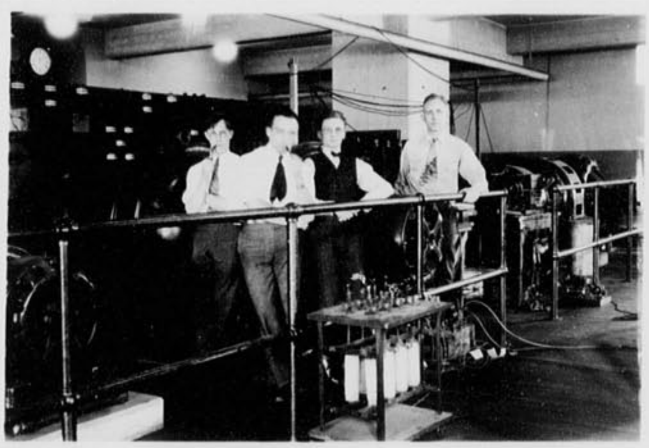
SLIP-TORQUE CURVE

May 22 1930
H. E. Edgerton

Photographs taken May 17, 1930
During tests of pages 34-35-

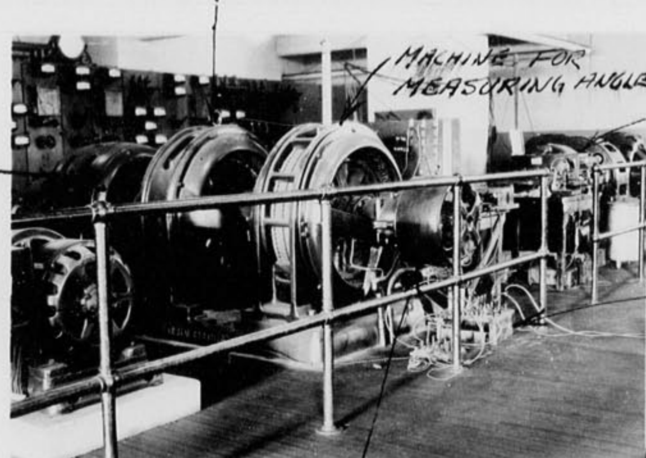


Chas Kingsley Sam Levine Paul Fourmarier Harold Edgerton



#302707
160 KW MOTOR BEING TESTED.

62.5KW
LOAD
MACHINE



oscillograph

change-over
switch.

Exciter used to
measure slip.

Notebook # 3

Filming and Separation Record

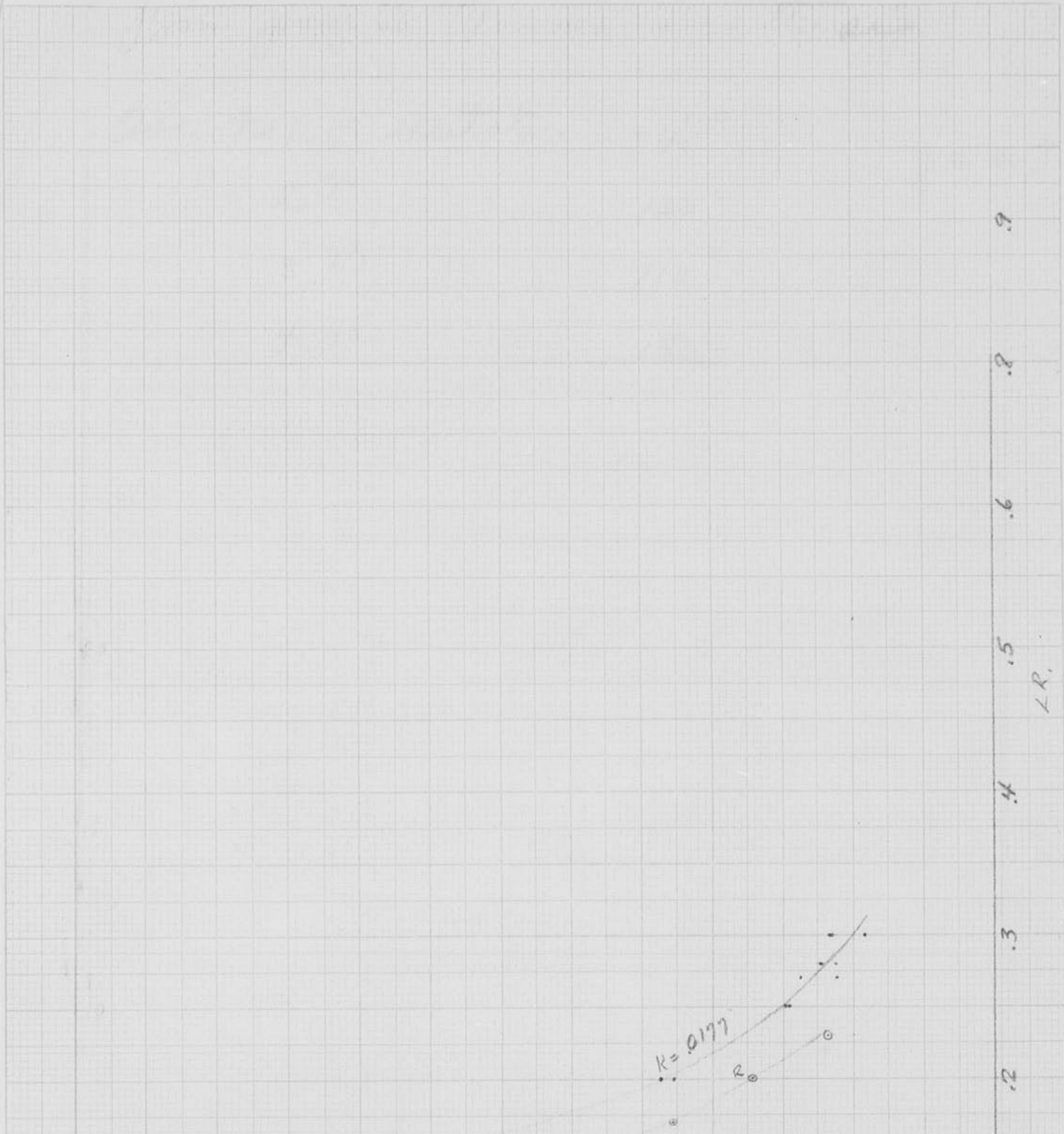
____ unmounted photograph(s)

____ negative strip(s)

1 unmounted page(s)
(notes, drawings, letters, etc.)

was/were filmed where originally located between page 40 and 41.

Item(s) now housed in accompanying folder.


R = .0177
R
LR.
.25
.20
.15
.10
.05
0

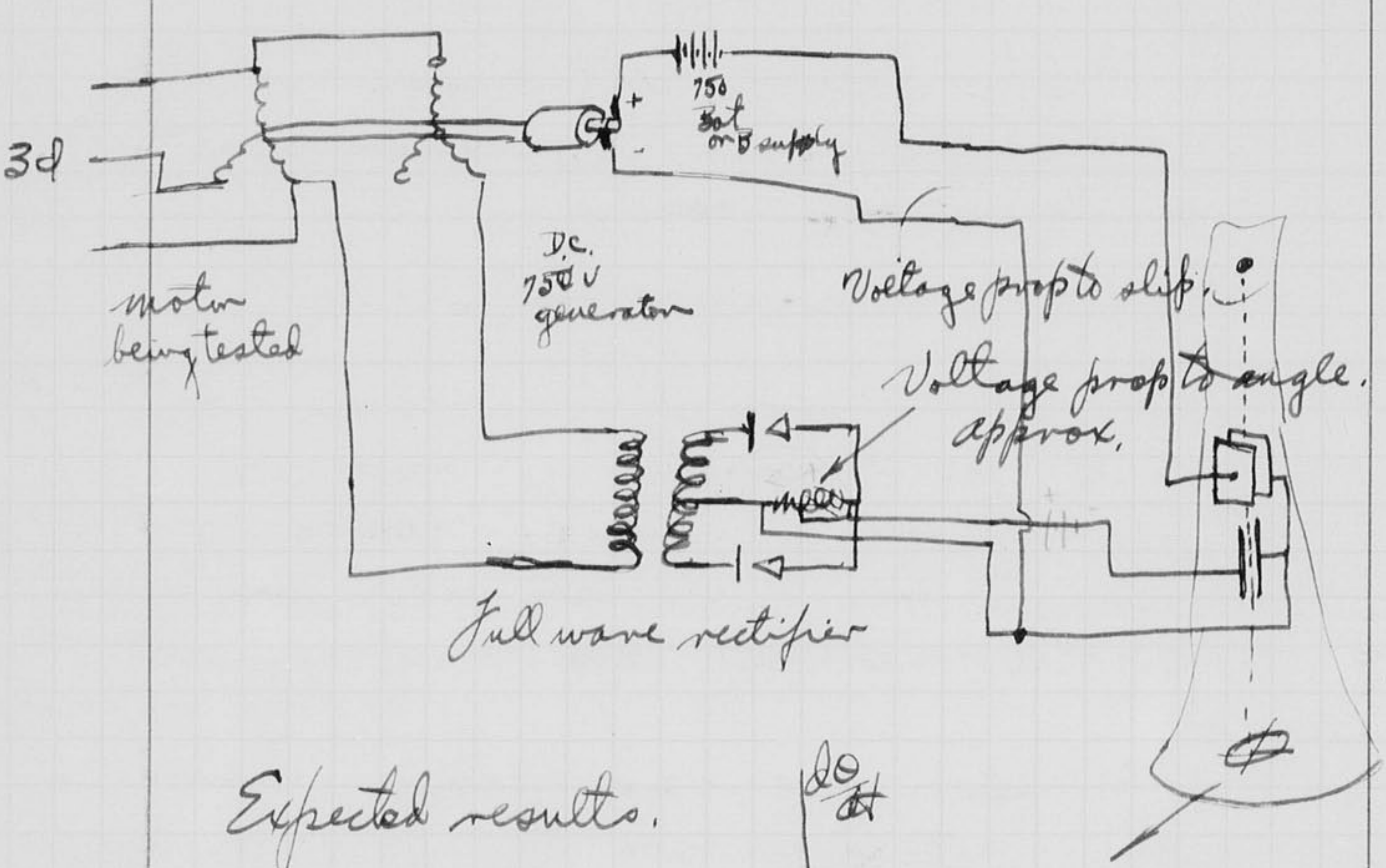
From page 68 Fourmarier's ~~thesis~~.

Osc No 1. 27 excitation	-40°		$g = 0.7$
2 26	130°		
3 23	110°		
4 28	150.		

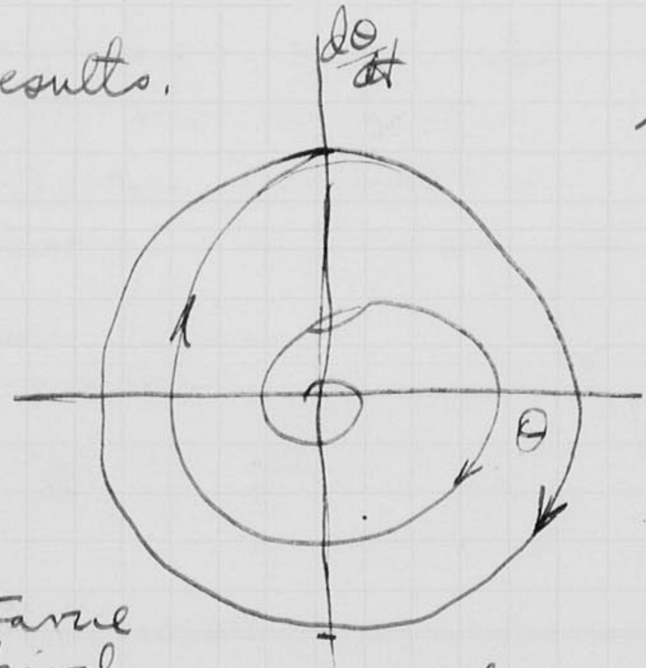
Oct 22, 1930
H. E. Edgerton

Method of Measuring
Slip-angle curves for a hunting motor.

A W.E. Braun tube can be used to give a plot of slip against angle by the method shown.



Expected results.



The spot will give an increasing spiral if the damping is negative.
If the damping is positive any disturbance will give a spiral that decreases to a point at the center.

Determination of the Moment of Inertia of a Synchronous Machine by Measuring its Hunting Period.

The motional differential equation of synchronous torques that determines the angular transients of a synchronous machine that is connected to an infinite bus is the following:

$$P_j \frac{d^2\theta}{dt^2} + P_m \sin \theta = \text{load (any function of time)}$$

The electrical damping term has been neglected since it is usually small. The first term represents the torque that is due to the acceleration or deceleration of the combined rotating mass of the motor and load. The second represents the synchronizing torque between the two components of magnetic field which are due to the applied armature voltage and the field current.

The coefficients P_j and P_m will now be determined in units of kilowatts, electrical degrees, and seconds.

Inertia torque = $J\alpha$ in pound feet

where $J = \frac{WR^2}{g}$ = the moment of inertia in poundals

α = the angular acceleration in mechanical radians per second^2.

Inertia power = $\frac{2\pi n}{60}(J\alpha) = \frac{2\pi n}{60}\left(\frac{WR^2}{g}\right)\alpha$ in pound feet per second.

If we express the acceleration in electrical degrees per second^2 then

$$\alpha = \frac{2\pi}{180p}\frac{d^2\theta}{dt^2}$$

since 2π mechanical radians = 180 p electrical degrees.

The expression for the inertia power can be now written in terms of kilowatts, electrical degrees, and seconds as

$$\text{Inertia power in kilowatts} = \frac{2\pi n}{60}\left(\frac{WR^2}{g}\right)\left(\frac{2\pi}{180p}\right)\frac{d^2\theta}{dt^2}\,\frac{.746}{550}$$

$$= P_j \frac{d^2\theta}{dt^2} \qquad (2)$$

where $P_j = 0.154 \times 10^{-6} \frac{n(WR^2)}{p}$ or $18.5 \times 10^{-6} \frac{f}{p^2}(WR^2)$

since $n = f\frac{120}{p}$ r.p.m.

The maximum synchronizing power for a three-phase round-rotor synchronous machine which has negligible armature resistance is

$$P_m = \frac{3\ VE}{1000\ x} \text{ kilowatts} \qquad (3)$$

where V = terminal phase voltage

E = induced phase voltage due to the field current.

x = synchronous reactance per phase.

If the magnitude of the angular oscillation is not large then the slope of the power angle curve may be considered as a straight line. This assumption makes equation 1 a linear differential equation. The slope of the power-angle curve is

$$\text{Slope} = P_m \frac{\pi}{2}\,\frac{\cos\theta}{90} \text{ kilowatts per electrical degree}$$

and the linear differential equation is

$$P_j \frac{d^2\theta}{dt^2} + P_m \frac{\pi}{2}\,\frac{\cos\theta}{90}\,\theta = \text{load in kilowatts.}$$

Notebook # 3

Filming and Separation Record

____ unmounted photograph(s)

____ negative strip(s)

1 unmounted page(s)
(notes, drawings, letters, etc.)

was/were filmed where originally located between page 44 and 45.

Item(s) now housed in accompanying folder.

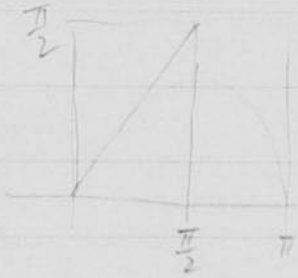
$$P_R = \frac{P}{\theta}$$

$$f = \frac{\cancel{120}\, p n}{120}$$

$$n = \frac{120 f}{p}$$

$$F = 0.268 \sqrt{\left(\frac{VE}{x}\cos\theta\right) \frac{p^2}{f}\left(\frac{1}{WR^2}\right)\frac{(120)^2 f}{(120)^2 f}}$$

$$= 0.268 \sqrt{\frac{\frac{VE}{x}\cos\theta\,(120)^2 f}{\cancel{120}\; n^2\, \cancel{f}}}$$



$$= \frac{0.268 \times 120}{n}$$

$$= \frac{1}{2\pi}\sqrt{\frac{1}{18.5\times10^{-6}\frac{f}{p^2}WR^2}\cdot\frac{P_m \frac{\pi}{2}\cos\theta}{\frac{\pi}{2}}\;\frac{\frac{\pi}{2}}{90}}$$

$$= \frac{1}{2\pi}\sqrt{\frac{1}{18.5\times10^{-6}}}\sqrt{\frac{p^2}{f\,(WR^2)}\frac{f\,(120)^2}{f\,(120)^2}}\;P_R$$

n^2

$$= \frac{120\times10^3}{2\pi\,\cancel{10^3}}\sqrt{\frac{1}{18.5}\frac{\pi}{180}}\;\frac{1}{n}\sqrt{\frac{f}{WR^2}}\;P_R.$$

.054

2400

$$= 0.233$$

$\sqrt{\frac{\pi}{180}}$ $\frac{120\times10^3}{6.28}\times .233 =$ 4430. cyc second

588. cyc per second

3540 cyc per min

.01744

180) 3.00

.132

The differential equation is analagous to a series circuit of inductance L and capacity C which has the differential equation

$$L\frac{d^2 q}{dt} + \frac{q}{c} = E.$$

The natural frequency of oscillation of an electrical circuit is known to be

$$F = \frac{1}{2\pi}\sqrt{\frac{1}{Lc}} \qquad \text{cycles per second.}$$

Similarly the frequency of mechanical oscillation is

$$F = \frac{1}{2\pi}\sqrt{\frac{1}{P_j} \quad \frac{P_m \overset{\pi}{\overline{E}} \cos\theta}{90}}$$

$$= 0.268 \sqrt{\frac{VE\, p^2 \cos\theta}{x\, f\, (WR^2)}}$$

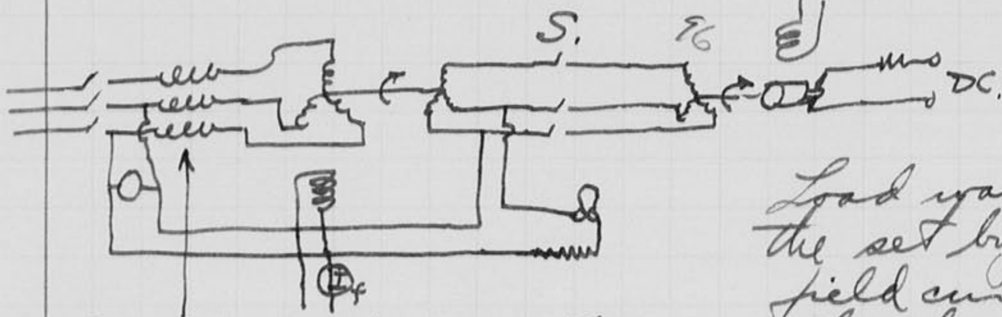
Solving for the moment of inertia

$$WR^2 = 0.072 \; \frac{VE\, p^2 \cos\theta}{x\, f\, F^2}$$

H. E. Edgerton
M.I.T. Nov. 15, 1930

H. S. Edgerton.
Nov. 16, 1930.

WR^2 from Hunting tests.



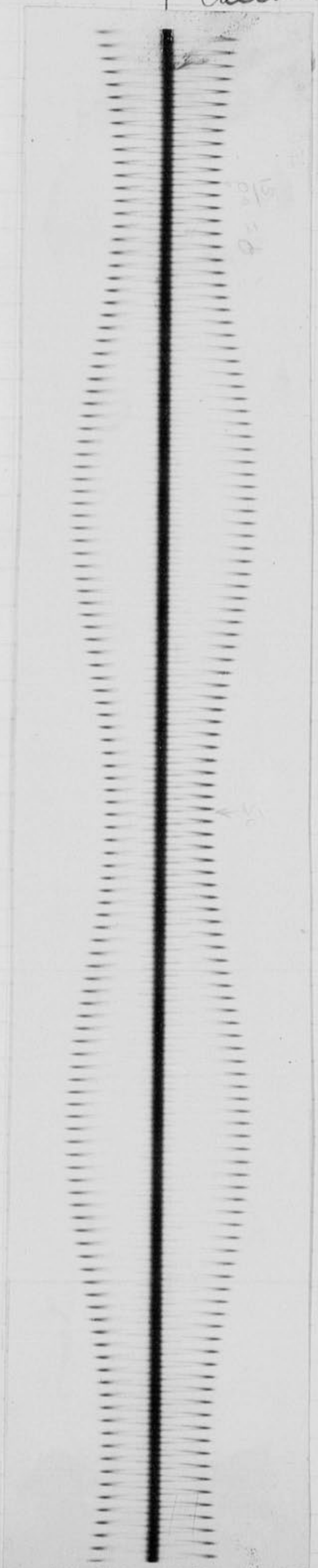
Reactors series connection
good for 30 amperes.

Load was put on the set by changing field current on the d-c machine. then switch S was opened and this sudden removal of load allowed the set to swing about its no load angle. the quadrature field was open circuited and so the damping was negligible.

An oscillogram was taken when the circuit conditions were as follows.

$V =$ 232 volts line to line.
$I_f =$ 8.4 amperes.
$I_{ac} =$ 5 ± amps.

Calculation of WR^2 from data of preceding page.



$V = \frac{232}{\sqrt{3}}$

$E =$

$p = 6$ (number of poles)

$\cos\theta = 1$

$x =$

$f = 60$ cycles/sec

$F =$ cycles/sec.

$$0.072 \frac{V E p^2 \cos\theta}{x f F^2} =$$

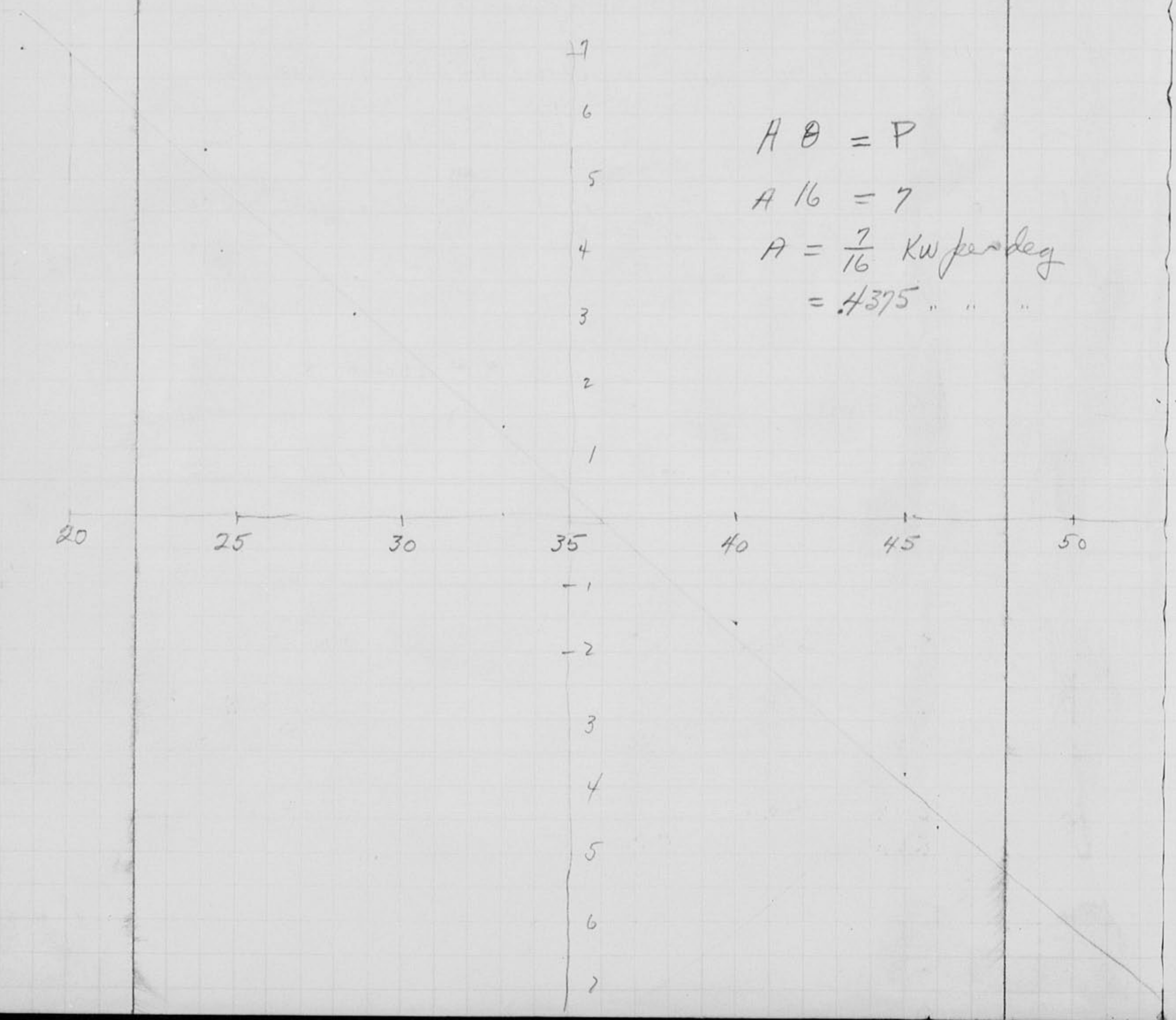
See next page.

2KVA 804 B. Syn Generator.

Starting Condition

60cycles	V_{stator}	18	17	16	23.5	28.0	27.0
	V field	186 volts			285		

When cold this motor will not start with 162 volts



$A\,\theta = P$

$A\,16 = 7$

$A = \frac{7}{16}$ KW per deg

$= .4375$ " " "

Power-Angle Curve of 804 A. Nov 17 1930

Reactor in series 804A.

θ	I_1	I_2	I_3	KW₁	KW₂	V	I_f	E_{KW}
+40.0	4.2	–	3.75	×2 .37 M	×2 .43 M	227	8.15	-1.60
+45.0	9.8	9.5	9.0	×2 .94 M	×2 .95 M	227	8.15+	-3.78
+33.0	3.25	—	3.65	×2 .29 G	×2 .39 G	226.5	8.10	+1.36
28.5	7.50	7.5	7.8	×2 .68 G	×2 .82 G			+3.0
24.0	–	12.8	13.0	×4 .565 G	×4 .71 G	228	8.05	+5.4
19.0 18.0	–	17.6	17.9	×4 .74 G	×4 .985 G	226	8.0	+6.9
46.0	–	11.8	11.0	×4 .59 M	×4 .56 M	225.5	8.05	-4.6
53.0	–	19.2	18.3	×4 .98 M	×4 .875 M	226	8.05	-7.42

$\frac{232.8.4}{226\,8.1}$

$1\ \frac{50}{60}$ ~~sec~~

$F = \frac{60}{50}$

Short circuit of 804A + reactors as used in tests.

I_f	I_a	E
2.05	16.2	
3.55	28.2	
3.60	28.2	109
4.95	38.9	
4.99		150
6.16	48.2	
6.16		182

$$F = \frac{1}{2\pi}\sqrt{\frac{1}{P_j}\,0.4375}$$

$$P_j = \left(\frac{1}{2\pi}\right)^2 \frac{1}{F^2}\,0.4375$$

$$WR^2 = \left(\frac{1}{2\pi}\right)^2 \frac{1}{F^2}\,0.4375\,\frac{P^2 \times 10^6}{18.6 f}$$

$$WR^2 = \left(\frac{50}{2\pi\,\cancel{60}}\right)^2 0.4375\,\frac{\cancel{36} \times 10^6}{18.6\ 60}$$

$= 247$ pound feet^2

$=$ 267.

Dec 12 1930
Prof. E. Bryant Jr.
Chas. Kingsley Jr.
Movies by Paul
J. Out[illegible]

Synchronizing tests
Movies of pulling into step phenomena.

No.	P_{KW}		I_f	I_m	Remarks.	
1	0		0		regular start,	
2	33 KW	185V	9.6	15.5	pullin ok. after start.	10 ft
3	36	195	10.0	15.5		10 ft
4	Ditto.			15.0		5 ft
5	Ditto			15		5 ft
6	Ditto			14. amp.	failed to pull in.	8 ft.
7				14.	pullin ok.	
8	33.[illegible]	[illegible]	10.0	13.9	Did not syn.	
9.	33.5	195	10.0	13.8	" " "	
10.	28.0	170	8.5	12.2	two shots.	
11.	0	0		10±2	Brought up to step pull in as reluct motor with wrong polarity.	

Two 1000 watt lamps were hung above the set and were used in taking movies of the starting. Mr. Kingsley posed for the picture at the starting panel.

The film speed was 16 frames per sec. the opening F 1.9. 16 mm film. Panchromatic. Eastman.

Dec 15 1930. These films came back last Thursday and they were fine. I put on a show Friday evening in the lab.

Notebook # 3

Filming and Separation Record

____ unmounted photograph(s)

1 negative strip(s) inside mounted envelope Pg. 51

____ unmounted page(s)
(notes, drawings, letters, etc.)

was/were filmed where originally located between page 50 and 51.

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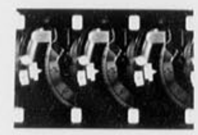


Moving Picture Photographs of 10 pole
Synchronous Motor. 1,9 lens 16 f.p.s.
Panchromatic film. by Henry Lane.

For all strobograms of Jan 7 1931 by Prof. Bowles.

33 KW shaft load   10 amps ± field current

Karl Wildes.
3-4616
Dec 4 1982.

March 19 1931 ... [illegible]

Integraph Solutions of Salient Pole Motor.

$\frac{P_L}{P_m} = k \frac{d\theta}{dt}$

$= \frac{1.50}{.02} = 75$

Reluctance = 0.3 × P_m. $b = 0$

Draw #7

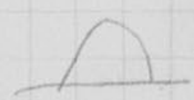
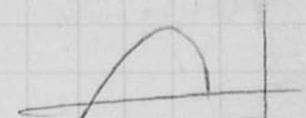
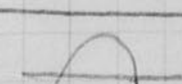
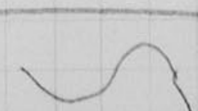
	$\frac{P_L}{P_m}$	k	θ_0	motor $\frac{d\theta}{dt}$		
	0.15	~~.02~~		1.20 / 7.5		Initial Steady State.
	.15	.0167	0		●	55° – 160
	.20	~~.02~~	0	.93/10.0		
.176	.167	.0167		.95 .95	42° ●	75 – 150±
.263 .25	.30	~~.02~~	0	.55/15.	0	~~unstable~~, very!
.22 .208	.25	~~.02~~	0	.74/12.5	●	103 – 149 ~~stable~~.
.238 .225	.27	~~.02~~	0	.60/13.5	●	122 –
.245 .233	.28	~~.02~~	0	.63/14	●	Very close to critical Just stable.
.250 .237	.285	~~.02~~	0		0	unstable.

k = .0167 instead of .02

wrong

March 20 1930 Ditto. k = .0177

chart 2

	P_2/P_m	k	θ_0	$\frac{d\theta}{dt}$ var.	$\frac{d\theta}{dt}$ avg.		
.132	1.5	~~.02~~ .0167	180	1.2 1.34	7.5	⊙	
.123	1.4	.02	180	1.2	7.0	⊙	
.105	1.2	.02	180		6.0	•	
.114	1.3	.02	180	1.3	6.5	○	
	2.6						backwards 330° 32.
	2.3.			.72 .82			332 29. backward
	2.6	.02				"	
	2.0					"	
	1.7					"	
	1.4					"	
	1.6.						
	1.5						

From Chart 2.

$\frac{P_c}{P_m}$	θ_0
.14	238
	100
.17	264
	84
.20	290
	63

Chart 3. Mar 21 1931 Edgerton
Brown & Gemeshausen

$\frac{P_L}{P_m}$	θ_0	k	
.56	0	.045	●
.565	0	"	○
.38	180	"	○
.375	180	"	○
.370	180	"	○
.360	180	"	●

K = .0475

critical at .365?

Chart 3a

Test of Integraph.

$k = 0$

$\frac{P_L}{P_m} = 1$ slope through 90°

straight line for $f(\theta)$ force

1mm

.39	0	.03	●	
.40	0	.03	~~○~~	●
.39	0	.03		
.42	0	.03		○

K = .0318

Round Rotor $P_R = 0$.

4.5 about critical.

March 28 1931 Chart 4. R = 0635

New Integraph setup II

$\frac{P_L}{P_n}$	θ_0	$\frac{d\theta}{dt}_{var}$	k	$d\theta/dt$	inch $\frac{d\theta}{dt}$	
.68	0		0.06	11.33	6.01	●
.70	0		"		6.18	o
.69	0		"		6.09	●
.53	180				4.68	

Mar 29 1931.

chart 5?

Integraph setup V. on sliptable .375 in = 1 unit of slip.

P_L/P_M	θ_0	k	$d\theta/dt$ units	$d\theta/dt$ inches	
.715	0	0.06	11.59	4.46	0.
.690	0	.06	1	4.32	●
.53	180	.06		3.315	0
.52	"	.06		3.25	.0
.51	"	.06		3.19 very close	0

Reverse Solutions — chart 6

k R = .06

P_L/P_M = .67 (.119")	.63	.59	.55	.52
θ				
116 (final)	118 ●	121.5 ●	124. ●	127 ● (final angle)
36 ●	52 ●	62 ●	72 ●	77 ●
340 ●	310 ●	281 ●	254 ●	227 ●
				112 ●

P_L/P_M	θ	k	$d\theta/dt$	$d\theta/dt$ inches	
.53	77°	.06		3.315	● barely
.53	80°	.06		"	0 ● second swing is just
.54	77.5	.06		3.38	000 out on 3 rd swing - just.

Round Rotor Solution.

.70	0	.06		4.37

K = .085

Chart 7. Setup V.

P_c/P_m	k	θ_0	$\frac{d\theta}{dt}$ unit.	$\frac{d\theta}{dt}$ inch		
.84	.085	0		3.95	●	?
.82	"	0		3.855	●	
.85	"	0		3.995	○	close.
.72	"	180		3.38	○	
.68		180		3.20	○	close
.67				3.15	●	

The scale on the θ table was in error for the solution the k slope is correct on this page but needs to be corrected by

$$1/\sqrt{\frac{8.45}{9.39}} = \frac{\cancel{}}{1.058} = 1.058$$

for all values up to now

that is k as noted should be 1.058 k.

April 1, 1931.

Determination of the conditions wherein a Salient-Pole Synchronous Motor pulls into step as a Reluctance Motor,

The equation stating the restrictions is

$$P_j \frac{d^2\theta}{dt^2} + P_d \frac{d\theta}{dt} + \underline{P_R} \sin 2\theta = \underline{P_L}$$

First change variables so that $2\theta = \alpha$

$$P_j \frac{d^2\left(\frac{\alpha}{2}\right)}{dt^2} + P_d \frac{d\left(\frac{\alpha}{2}\right)}{dt} + \underline{P_R} \sin\alpha = \underline{P_L}$$

$$P_j \frac{d^2\alpha}{dt^2} + P_d \frac{d\alpha}{dt} + 2\underline{P_R} \sin\alpha = 2\underline{P_L}$$

Change time variable so that $t = \frac{\lambda}{a}$.

$$a^2 P_j \frac{d^2\alpha}{d\lambda^2} + a P_d \frac{d\alpha}{d\lambda} + 2P_R \sin\alpha = 2P_L$$

$$\frac{d^2\alpha}{d\lambda^2} + \frac{aP_d}{a^2P_j} \frac{d\alpha}{dt} + \frac{2P_R}{a^2P_j} \sin\alpha = \frac{2P_L}{a^2P_j}$$

now let $\frac{2P_R}{a^2P_j} = 1$

$$a = \sqrt{\frac{2P_R}{P_j}}$$

$$\frac{d^2\alpha}{d\lambda^2} + \frac{P_d}{P_j\sqrt{\frac{2P_R}{P_j}}} \frac{d\alpha}{dt} + \frac{\cancel{2P_R}}{\cancel{P_j}\frac{\cancel{2P_R}}{\cancel{P_j}}} \sin\alpha = \frac{\cancel{2}P_L}{\cancel{P_j}\left(\frac{2P_R}{\cancel{P_j}}\right)}$$

$$\frac{d^2\alpha}{d\lambda^2} + \frac{P_d}{\sqrt{2P_jP_R}} \frac{d\alpha}{dt} + \sin\alpha = \frac{P_L}{P_R}.$$

From the cylindrical rotor case then with

$$k \text{ as } \frac{P_d}{\sqrt{2 P_j P_R}} \text{ and } \frac{P_e}{P_R}$$

it can be found whether or not the conditions fall above or below the ultimate line for synchronization.

~~With $P_R = 0.3$~~

Unbalanced-Rotor Induction Motor

The torque equation for an induction motor with an unbalanced rotor is of this form

$$P_j \frac{d^2\theta}{dt^2} + P_d(1-b\cos 2\theta)\frac{d\theta}{dt} = P_L$$

$$\frac{d^2\theta}{dt^2} + \frac{P_d}{P_j}(1-b\cos 2\theta)\frac{d\theta}{dt} = \frac{P_L}{P_j}$$

or since $\frac{d\theta}{dt} = S.$

$$\frac{dS}{dt} + \frac{P_d}{P_j}\left(1-b\cos 2\int_0^t S\,dt\right)S = \frac{P_L}{P_j}$$

Or in another form by changing the units of time

let $t = \lambda/a$ $a =$ constant.

$$a^2 P_j \frac{d^2\theta}{d\lambda^2} + aP_d(1-b\cos 2\theta)\frac{d\theta}{d\lambda} = P_L$$

Let $a^2 P_j = 1$

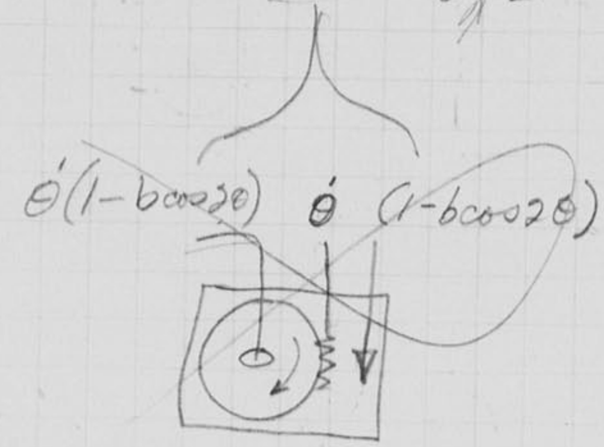
$$a = \frac{1}{\sqrt{P_j}}$$

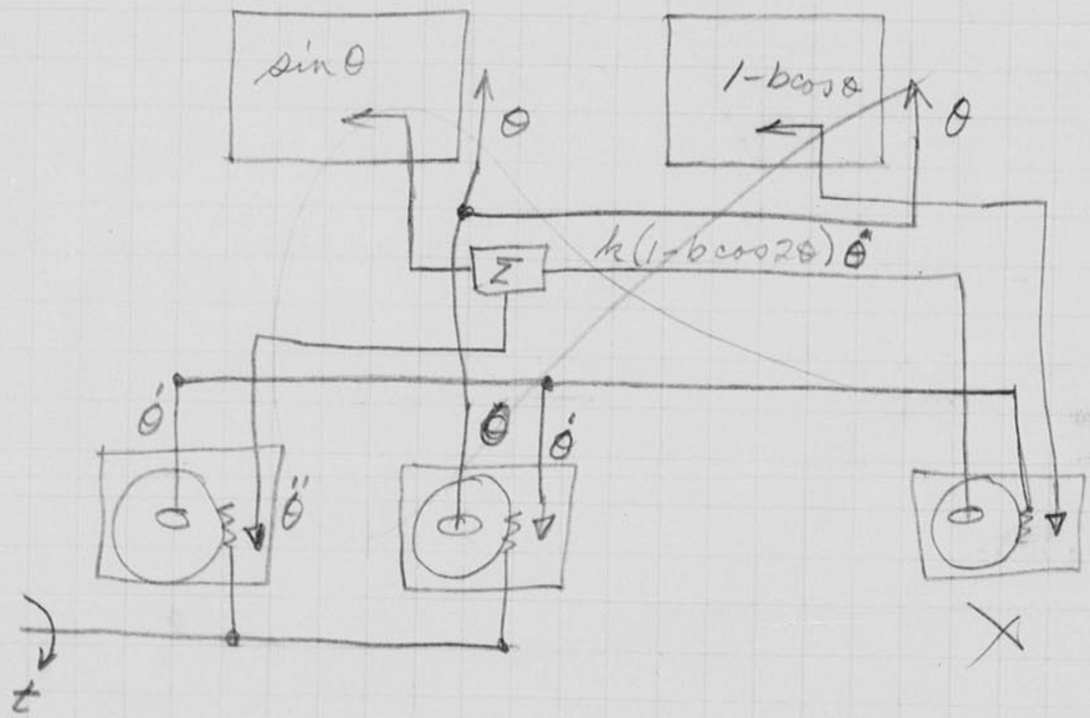
$$\frac{d^2\theta}{d\lambda^2} + \frac{P_d}{\sqrt{P_j}}(1-b\cos 2\theta)\frac{d\theta}{d\lambda} = P_L.$$

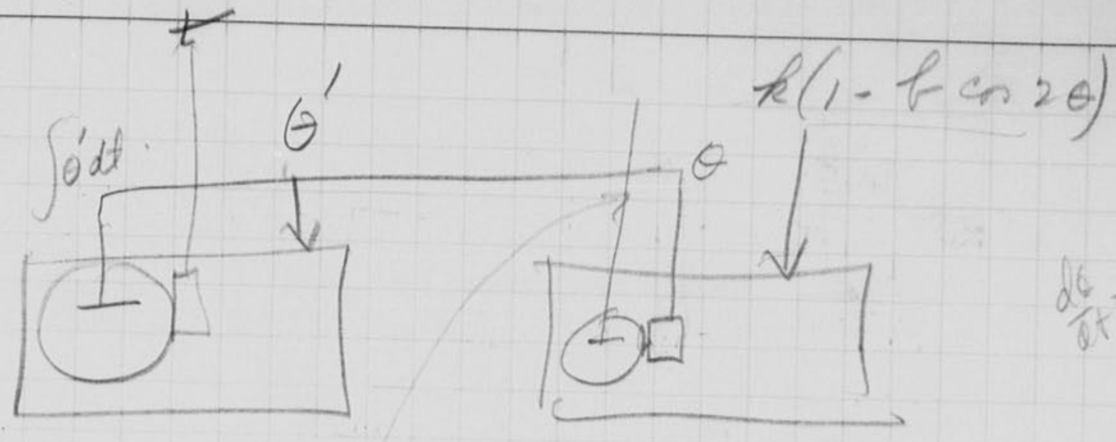
Steady state

$$\ddot{\theta} + k(1-b\cos 2\theta)\dot{\theta} = P_L$$

$$\theta = \int_0^t\!\!\int_0^t \left[P_L - \overset{.02}{k}\,(1-b\cos 2\theta)\dot{\theta}\right] dt\,dt$$







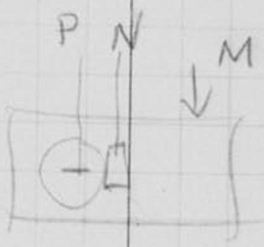
$\frac{d\theta}{dt} = \int d\theta.$

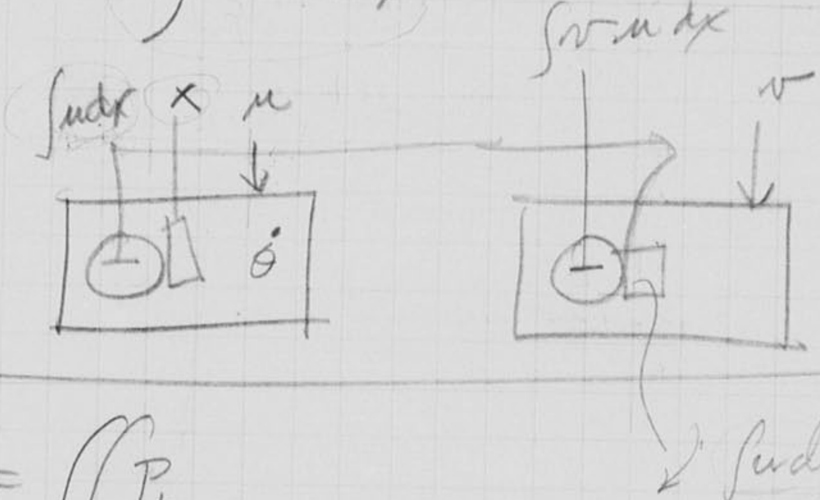
$\dot\theta = \int \frac{d\theta}{dt} dt$

$\dot\theta = \int d\theta.$

$$\int k(1-b\cos 2\theta)\,\theta' dt$$

$$\int uv\,dx$$





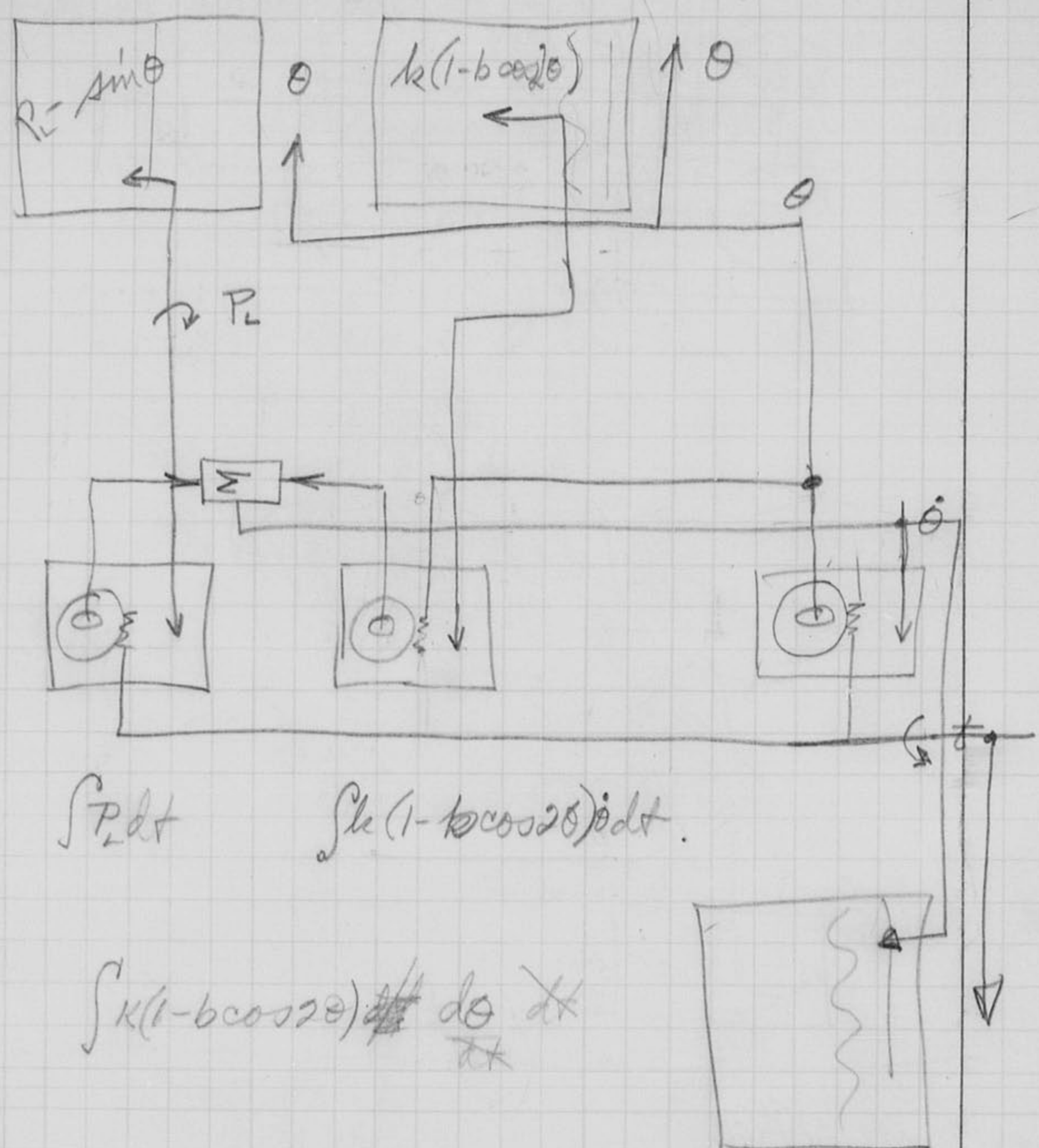
$$P = \int M\,dN$$

$$\theta = \iint P_L$$

$\int u dx$

$du \int u dx = u\,dx$

$$\theta = \int\left[\int P_L dt - \left(\int k(1-b\cos 2\theta)\,\dot\theta\,dt\right)\right] dt.$$



$\int P_L\,dt$ $\int k(1-b\cos 2\theta)\dot\theta\,dt$.

$\int k(1-b\cos 2\theta)\,\cancel{\dot\theta}\,d\theta\ \cancel{dt}$

Notebook # 3

Filming and Separation Record

1 unmounted photograph(s)

____ negative strip(s)

____ unmounted page(s)
(notes, drawings, letters, etc.)

was/were filmed where originally located between page 64 and 65.

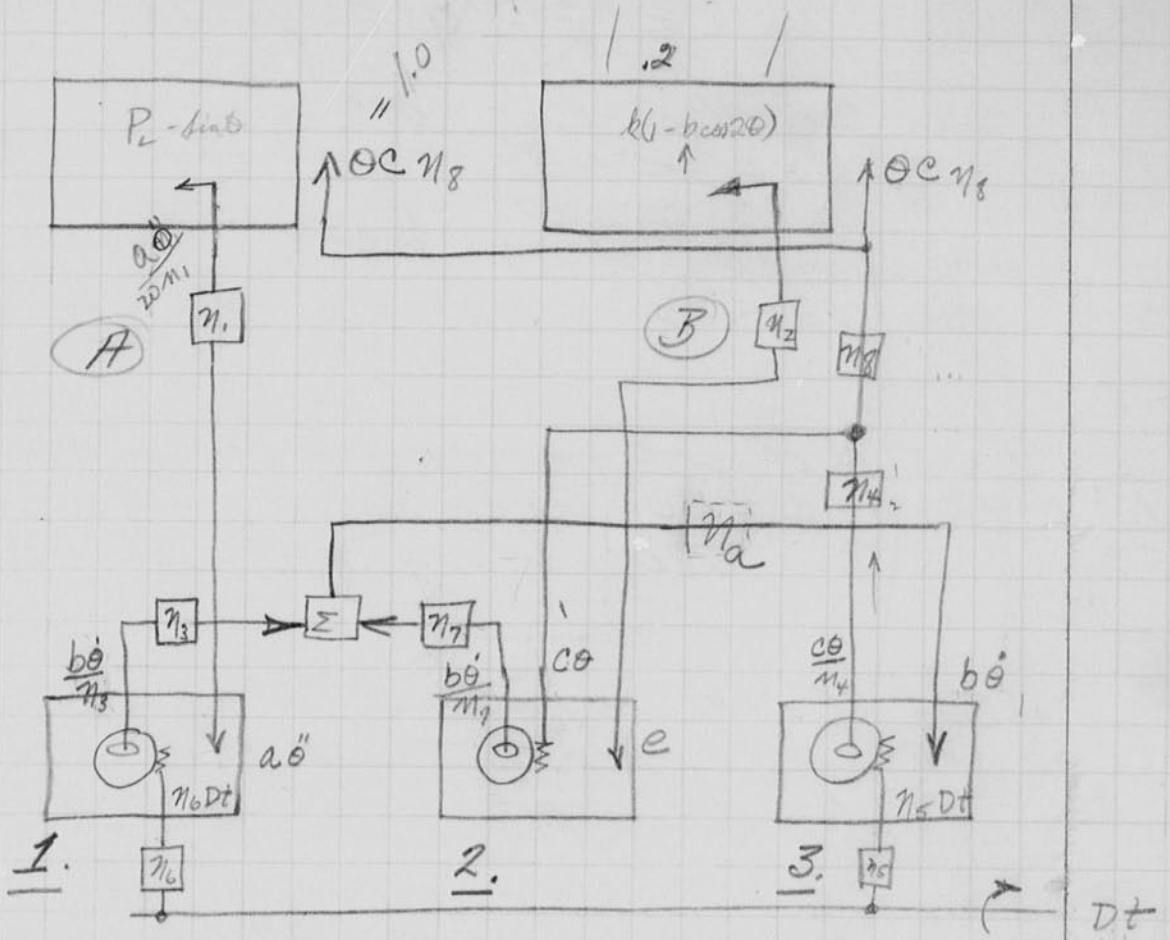
Item(s) now housed in accompanying folder.

Apr

Dt

Determination of Scales for non-linear damping Syn. Mach Prob.

April 5, 1931.



Integrator limitations

$a\ddot{\theta} < 40$ rev

$e < 40$ "

$b\dot{\theta} < 40$ rev.

$c\theta < 400$ rev. per min.

Unit relationships

1 $\quad \dfrac{b\dot{\theta}}{n_3} = \dfrac{1}{32}\displaystyle\int a\ddot{\theta}\, n_6 D\,dt \quad \rightarrow \quad 1 = \dfrac{n_3 n_6\, a\, D}{32\, b}$

2. $\quad \dfrac{b\dot{\theta}}{n_7} = \dfrac{1}{32}\displaystyle\int e c\, d\theta \quad \rightarrow \quad 1 = \dfrac{n_7\, e c}{b\, 32}$

3. $\quad \dfrac{c\theta}{n_4} = \dfrac{1}{32}\displaystyle\int b\dot{\theta}\, n_5 D\,dt. \quad 1 = \dfrac{n_4 n_5\, b\, D}{32\, c}$

$\ddot{\theta}$max is about 2 or less

$a = 16$ — so $a < \frac{40}{2} = 20$ rev/unit Let $a = 16$

max for e units $= 0.2$

$e = 128$ — $e \times 0.2 < 40$ $e < \frac{40}{0.2} = 200$ Let $e = 128$

$\dot{\theta}$ max is about 20

$b = 2$ — $b\dot{\theta} < 40$ $b < \frac{40}{20} = 2$ let $b = 2$.

Plot Q chart on no A table so

$c = 1.$ — that $c = 1.0$ also let $n_8 = 1.0$

$n_8 = 1.$ — then 180 elect deg. = 9.0 inches

Trial VI Unit equations become

1. $1 = \frac{n_3 n_6 a D}{32 b} = \frac{n_3 n_6 D}{4}$

$n_7 = 1/2$ — 2. $1 = \frac{n_7 e c}{b 32} = 2 n_7$

3. $1 = \frac{n_4 n_5 b D}{32 c} = \frac{n_4 n_5 D}{16}$

There are left 5 unknowns and two equations so that three quantities may be selected at random.

$n_3 = 1/2$

$n_4 = 1/2$ — Let $n_3 = 1/2$ $n_4 = 1/2$ $n_5 = 1.$

$n_5 = 1$

$D = 32$ — from 3. $1 = \frac{1/2\ 1}{16} D$ $D = 32$

$n_6 = 1/4$ — from 1 $1 = \frac{\frac{1}{2}\ n_6\ 32}{4}$ $n_6 = 1/4$

Check.

1. $1 = \frac{n_3 n_6 a D}{32 b} = \frac{\frac{1}{2}\frac{1}{4}\ 16\ 32}{32 \times 2} = 1$ ✓

2. $1 = \frac{n_7 e c}{b 32} = \frac{\frac{1}{2}\ \cancel{128}\ 1}{2\ \cancel{32}} = 1$ ✓

3 $1 = \frac{n_4 n_5 b D}{32 c} = \frac{1/2\ 1\ 2\ \cancel{32}}{\cancel{32}\ 1} = 1$ ✓

Units (verticle) on B table).

$\eta_2 = 1/8$

$e = 128$ revs/unit.
Let $\eta_2 = 1/8$

$$\frac{e}{20\eta_2} = \frac{128}{20\times\frac{1}{8}} = \underline{51.2 \text{ inches}} \text{ per unit.}$$

Units (verticle) on A table.

$\eta_1 = 1/8$

$a = 16$ revs/unit
Let $\eta_1 = 1/8$

$$\frac{a}{20\eta_1} = \frac{16}{20\frac{1}{8}} = \underline{6.4 \text{ inches/unit.}}$$

Horizontal scale on A and B tables is the same and is equal to
9" = 180 elect degrees

---

trial VII Incase $k = 0.05$ or less, the e scale can be doubled to 256 rev/unit
The verticle scale would then become

$$\frac{e}{20\eta_2} = \frac{258}{20\frac{1}{8}} = 102.4 \text{ inches/unit.}$$

Since e only appears in unit equat 2 and since c and b are fixed, η_7 needs to be changed in the opposite sense to e

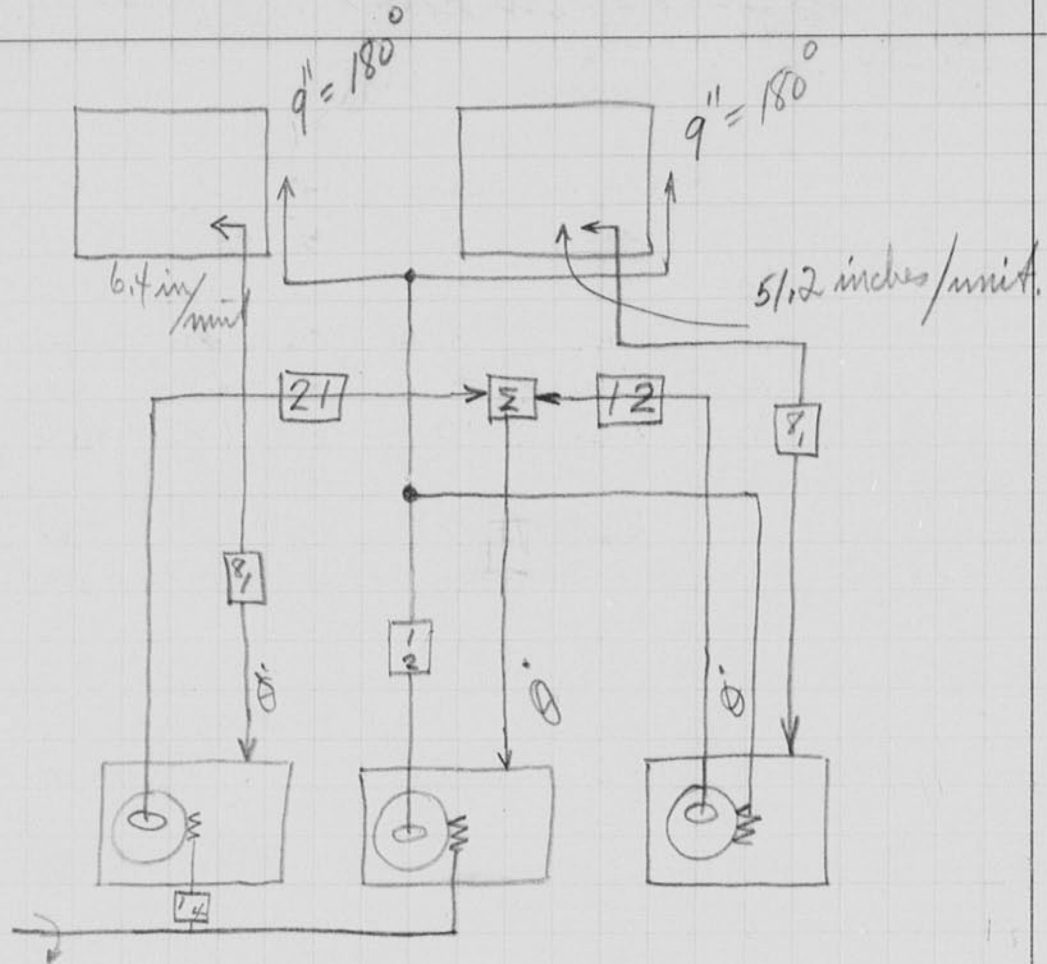
$\eta_7 = 1/4$

(2) $$1 = \frac{\eta_7 e c}{b32} = \eta_2 \frac{\overset{128.4}{256} \cancel{1.0}}{32\times 2} = \eta_7 4 \qquad \eta_7 = 1/4$$

or $e = \overset{512}{\cancel{204.8}}$ for $\eta_7 = 1/8$ scales VII

$e = 204.8$ " $\eta_7 = 1/4$
$e = 102.4$ for $\eta_7 = 1/2$

scales I



Setup for scales VI

Effect of the time constant of the field circuit.

April 5, 1931.

The inductance of the field circuit will retard the build up of the synchronizing torque in approximately an exponential relationship. That is the synchronizing force is ~~actually~~ more closely represented by $\left[P_m(1-\varepsilon^{-\alpha t})\sin\theta\right]1$ than $(P_m \sin\theta)1$.

$$P_j\frac{d^2\theta}{dt^2}+P_d\frac{d\theta}{dt}+\left[P_m(1-\varepsilon^{-\alpha t})\sin\theta\right]1=P_L.$$

$$\frac{d^2\theta}{dt^2}+\frac{P_d}{P_j}\frac{d\theta}{dt}+\left[\frac{P_m}{P_j}(1-\varepsilon^{-\alpha t})\sin\theta\right]1=\frac{P_L}{P_j}.$$

Let $t=\frac{\lambda}{a}$ where λ = new variable.

$$a^2\frac{d^2\theta}{d\lambda^2}+\frac{aP_d}{P_j}\frac{d\theta}{d\lambda}+\left[\frac{P_m}{P_j}(1-\varepsilon^{-\alpha\frac{\lambda}{a}})\sin\theta\right]1=\frac{P_L}{P_j}$$

$$\frac{d^2\theta}{d\lambda^2}+\frac{P_d}{aP_j}\frac{d\theta}{d\lambda}+\left[\frac{P_m}{a^2P_j}(1-\varepsilon^{-\frac{\alpha}{a}\lambda})\sin\theta\right]1=\frac{P_L}{P_j a^2}$$

Now Let $\frac{P_m}{a^2P_j}=1$

or $a=\sqrt{\frac{P_m}{P_j}}$

which gives

$$\frac{d^2\theta}{d\lambda^2}+\frac{P_d}{\sqrt{P_jP_m}}\frac{d\theta}{d\lambda}+\left[(1-\varepsilon^{-\frac{\alpha}{a}\lambda})\sin\theta\right]1=\frac{P_L}{P_m}$$

$$\theta=\iint\left\{\frac{P_L}{P_m}-k\frac{d\theta}{d\lambda}-\left[(1-\varepsilon^{-\frac{\alpha}{a}\lambda})\sin\theta\right]1\right\}d\lambda\, d\lambda$$

$$=\int\left\{\int\frac{P_L}{P_m}d\lambda-\int k\frac{d\theta}{d\lambda}d\lambda-\int(1-\varepsilon^{-\frac{\alpha}{a}\lambda})\sin\theta\, 1\, d\lambda\right\}d\lambda$$

Slip variations due to a Reluctance torque equal to .3 Pm. Values taken from charts 1 to 2 inc.

Chart	L.R.	k.	$\dot\theta_{max}$ "	$\dot\theta_{min}$ "	$\dot\theta_{max}-\dot\theta_{min}$	avg $\dot\theta$ $\frac{\dot\theta_{max}+\dot\theta_{m}}{2}$	$\frac{\dot\theta-\dot\theta}{\dot\theta+\dot\theta}$ % var.	or p 52 % var
1.	.15	.0177	1.62	~~1.4~~	.22	1.4	15.7	16.
p.52.	.20	"	2.05	~~1.88~~	.17	1.88	9.05	9.5
	.25	"	2.48	~~2.34~~	.14	2.34	5.98	5.92
	.27	"	2.68	~~2.54~~	.14	2.54	5.52	4.45
	.28	"	2.76	~~2.63~~	.13	2.63	4.95	4.5
	.30	"	2.93	~~2.80~~	.13	2.80	4.65	3.67
	.15	"	1.63		.22	1.41	15.6	16.0
	.14	"	1.55		.24	1.31	18.35	17.4
	.13	"	1.46		.25	1.21	20.65	20.0
	.12	"	1.38		.28	1.10	25.40	—
					$\theta_{max}-\theta_{avg}$	avg.		
2.	.14	"	3.48	2.61	.40	3.08		13.0
	.17	"	4.09	3.38	.34	3.75		9.07
	.20	"	4.70	4.09	.30	4.40		6.82
	.23	"	5.30	4.77	.24	5.06		4.75

April 8 1931 — Solutions with set ups of page 68. scales VI

Cylindrical rotor check.

$$\frac{512}{4} \quad 204.8$$

P_L/P_m	k	$\dot{\theta}_0$	$\dot{\theta}_0$				
0.6	.05	12.0	0	● close.			Perfect check of Brown & Gimeshausen.
0.605	.05	12.1	0	○ close			

P_L/P_m	k	$\dot{\theta}$	$2\times\dot{\theta}$	512k	θ_0	$\dot{\theta}_{max}$		
.89	.12	7.42	14.84	614	180		● close	
.90	.12	7.50	15.0	"	180		● closer.	
.915	.12	7.62	15.24 (.858°)	"	180		critical.	
.97	.14	6.93	13.86 (310°)	7.2	180	24.75	●	close.
.98	.14	7.0	14.0	7.2	180		●	closer.

η changed to 1/8 from 1/2 k scale thereby modified (see page 67.). 4.8 inches per ton. Scales V

	P_L/P_m	k	$\dot{\theta}$	$2\dot{\theta}$	K (204.8)	θ_0	$\dot{\theta}_{max}$		
Chart 8	.14	.01	14.0	28.0	2.064	0		●	30°
	.15	.01	15.0	30.0	"	○		○	
	.145	.01	14.5	29.0	2.064	0		○	close.
	.06	.01	6.0	12.0	2.064	180	31.3	○	
	.05	.01	5.0	10.	2.064	180		●	10°
	.055	.01	5.5	11.	2.064	180	31.75	●	1° close

Salient Pole case $P_R = 0.3 P_m$

	P_L/P_m	k	$\dot{\theta}$	$2\dot{\theta}$	K	θ_0	$\dot{\theta}_{max}$		
	.055	.01	5.5	11.0	2.064	180	32.3	○	Initial slip = 14.25
	.05	.01	5.0	10.0	2.064	180		○	second ●
	.04	.01	4.0	8.0	"	180	31.5	●	158°
	.14	.01	14	28	"	0		○	
31	.13	.01	13	26	"	0		●	45°
	.135	.01	13.5	27	"	0		●	
Chart 9	.38	.03	12.66	25.32	6.195	0		○	
	.37	.03	12.32	24.64	6.190	0		●	15°
	.21	.03	7.0	14.0	"	180	31	●	13°.
31	.22	.03	7.3	14.6 (216)	"	180		○	
	.38	.05	7.60	15.2 (73°)	10.32	180		●	
	.39	.05	7.8	15.4	"	"		○?	Study the final pt.

Changes of scales. Diagram on page 65

Given constants.

$a = 16$

$e = \cancel{128}$ (Depends upon scales).

$b = 2$

$c = 2 \quad n_8 = 1/2$ (These were $c = 1$ $n_8 = 1$).

the angle scales and plots remain the same as scales II and III.

Let $n_a = 1/4$

this gives a 4:1 scale relationship between the output slip on the resultant table of this VIII against that of II and III.

Unit equations

$$1 = \frac{n_3 n_a n_6 a D}{32 b} = \frac{n_3}{4}\,\frac{n_6\, 16\, D}{32 \times 2} = \frac{n_3 n_6 D}{16}.$$

$$1 = \frac{n_7 n_a e c}{b \times 32} = \frac{n_7 e \cancel{2}}{4 \times \cancel{2} \times 32} = \frac{n_7 e}{128}$$

(Let $e = \overset{512}{\cancel{204.8}}$ as in III) or 204.8 in/unit.

Then $n_7 = \frac{128}{512.0} = \frac{1}{4}$

$$1 = \frac{n_4 n_5\, b D}{32 c} = \frac{n_4 n_5\, 2 D}{32 \times 2} = \frac{n_4 n_5 D}{32} =$$

Let $n_5 = 1 \quad n_4 = 1/2 \quad n_3 = 1/2$

$n_4 n_5 D = 32 \qquad D = 32 \times 2 = 64$

$$n_6 = \frac{16}{n_3 D} = \frac{16}{64\, 1/2} = \frac{1}{2}.$$

Chart

April 11, 1931. (b = 1) Slip variations.

2048

	k	P_L/P_m	$\frac{d\theta}{dt}$	$2\frac{d\theta}{dt}$ unsymm. stable		$\dot\theta$ variation … $\dot\theta_{max}-\dot\theta_{avg}$		$-(\dot\theta_{min}-\dot\theta_{avg})$		% $\dot\theta_{max}$	% $\dot\theta_{min}$
9	.03	.1	3.33	6.67	→ 241°	$1.\frac{340}{360}$	1.935	$1.\frac{140}{360}$	1.389	21.0	20.8
	.03	.2	6.66	13.32 (240, 120)		$1^{297}/360$	1.825	$1.^{233}/360$	1.647	13.69	12.36
	.03	.3	10.	20.0		$1\frac{281}{360}$	1.778	$1\frac{220}{360}$	1.611	8.88	8.05
	.03	.4	13.33	26.66		$1\frac{287}{360}$	1.797	$1\frac{222}{360}$	1.617	6.74	6.06
	.03	.5	16.67	33.34		$1\frac{245}{360}$	1.689	$1\frac{240}{360}$	1.666	5.065	5.0
10	.015	.15	10.0	20.0		$\frac{310}{360}$	0.861	$\frac{300}{360}$	0.833	4.30	4.16
	.015	.075	5	10.0		$\frac{284}{360}$	.789	$\frac{284}{360}$	.789	8.87	7.89

~~Slip variation due to Reluctance Torque~~ .3 Pm.

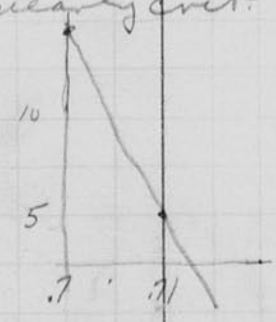
~~11. .03 .15 5.0 10~~ Cylindrical rotor Unbal. Rotor.

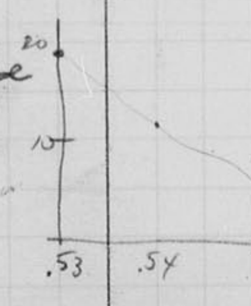
	k	P_L/P_m	$\frac{d\theta}{dt}$	$2\frac{d\theta}{dt}$	θ_0		
11	.03	.23	7.67	15.34	θ_0	●	Very stable.
	.03	.39	13	26.	0	●	
	.03	.42	14	28.	0	○	
	.03	.40	13.33	26.66	0	●	
	.03	.41	13.66	27.34	0	○	
12.	.03	.23	7.67	15.333	180	●	very.
	.03	.24	8.0	16.0	180	●	close. 40
	.03	.25	8.33	16.66	180	●	close 7° nearly crit.
	.03	.26	8.66	17.33	180	○	

No zero lost.

change $e = \frac{517}{2}$ $M_7 = 1/2$

	k	P_L/P_m	$\frac{d\theta}{dt}$	$2\frac{d\theta}{dt}$	θ_0		
13	.06	.70	11.67	23.33	0°	●	14°
	.06	.71	11.83	23.65	0°	●	5°
	.06	.72	12.0	24.0	0°	●	2° close.
	.06	.73	12.18	24.33	0°	○	
	.06	.53	8.83	17.66	180°	●	18° to spare
	.06	.54	9.0	18.0	180	●	12
	.06	.55	9.17	18.33	180°	●	8
	.06	.56		18.66	180	○	






50
40
%
30
20
10
0
K=.215
K=.03
.1
.2
.3
.4
.5
.6
.7
.8
.9
1.0
L.R.

April 12 1931.
G. E. Edgerton.

Reverse solutions.

$R = 0.06 \quad P_R = 0.3 P_m.$

Chart.	k	L.R.	θ FINAL.	θ start		$\dot{\theta}$ avg.	turns
14	0.06	.48	129.5	128.	✓	8.	16
	"	.51	128.0	126.5	✓		17
	"	.54	125.5	124.0	✓		18.
	"	.57	123.5	122.0	✓		19
	"	.60	121	119.5	✓		20.
	"	.63	119	117.5	✓		21.
	"	.66	117	115.5	✓		22
	"	.69	114.5	113.0	✓		23.
Forward solution							
	"	.63		$0 \stackrel{\circ}{=} \theta_0$		⊙ very stable? !!	

Forward check for cylindrical rotor
.06 .69 nearly critical o just barely Good check!

Some trouble was experienced with the integraph due to too much load on the angle shaft. This may explain some of the discrepancy of the days results.

April 14, 1931. Data from Integraph Solutions.

Chart no.	k.	θ_0	L.R.	$\dot{\theta}_0$ avg. inches	$\dot{\theta}_0$ inst. inches	$\dot{\theta}$ max. transient	$\theta = 180$ $\frac{\dot{\theta}_{max}}{\dot{\theta}_{avg}}$	$\theta = 0$ $\frac{\dot{\theta}_{max}}{\dot{\theta}_{avg}}$
1	.0177	180	.12	1.13	1.38	3.1	2.75.	1.22
3	.0475	180	.36	3.0	3.38	6.05	2.02.	1.13
5	.0635	180	.51	3.22	3.59	6.0	1.87	1.12
7	.085	180	.61	3.16	3.52	5.7	1.80	1.11
8	.01	180	.04+	.47	.66	1.56	3.32.	1.40
9	.03	180	.21	.71	.805	1.56	2.20	1.14
9.	.05	180	.38	.76	.88	1.52	2.0	1.16
20	.10	180	.796	.32	.36	5.61	1.77	
19	.02	180	.13	.247	.—	6.3	2.55	

Chart 14. intersections.

$k = 0.06$
$P_R = 0.3\, P_m.$

L.R.	Steady State $\dot{\theta}$ average	$\dot{\theta}$ max	$\dot{\theta}$ min	$\frac{\dot{\theta}_{max}}{\dot{\theta}_{min}}$ SS	transient $\dot{\theta}$ max	θ_0	θ_0.
.48	3.2		3.6			83	
.51	3.4		3.8			76°	240
.54	3.6		3.95			70	262
.57	3.8		4.18			60.5	281
.60	4.0		4.35			31.5	298.5
.63	4.2		4.51			37.5	314
.66	4.4		4.72.			16.5	342
.69	~~4.6~~						

April 18-1931
H E Edgerton

Integraph Solutions.

Setup as outlined on page ~~XX~~ 73

Damping scale = ~~204.8~~ 102.4 inches / unit on table ~~X~~ 2.

$N_7 = 1/2$.

Reverse solutions.

.06
1.02
.06
0.14

$16 \times .49 = .783$

Chart	k.	L.R.	θ FINAL	θ Start	θ̇ avg.	θ̇ turns
	0					
~~14~~ 15	0.06	.49	129	127.5	8.17	16. 1/3 ~~16. 2/3~~
	,06	,50	127.5	126.0		16 2/3
	,06	.51	~~128~~ 127	~~126.5~~ 125.6		
	,06	.50	127.5	126.0		

Speed variations due to reluctance torque.

16	0.06	.3	5	10
		.6	10	20
		.9	15	30.

April 19, 1931. Cont of speed variations

0.04	~~.3~~ .2	5 ~~7.5~~	~~15~~	10
	~~.6~~ .4	10		20
	~~.9~~ .6	15		30

Pulling into step equa

			θ°	θ̇	turns	
17.	0.06	.48	180°	8	16.	0 just! .475 probably stable.
	,06	,65	0	10.84	21.65 230	● quite stable
	.06	.67	0		22.30 110	0 ? belt off.

Reverse Solutions $P_R = 0.3\ P_m$ $b = 0$

Chart	k	LR	θ_{final}	θ_{start}	$\dot{\theta}_{avg}$	$\dot{\theta}_{turns}$	θ_0	θ_0
17	0.04	.32	141.5	140	8	16	98°	226
		.36	139.	138.5	9	18	79.0	256
		.40	135	133.5	10	20	67.0	283
		.44	132	130.5	11	22	48.5	307
		.48	128.5	127.5	12	24	13°	345
		.34	140.5	139.0	8.5	17.	86.0	243

Forward tests. 8.18 inch.

			θ_0	$\dot{\theta}$	turn.		
18	0.08	.64	180°	8	16	• very close 2 or 3°	
	~~08~~	~~.645~~	~~180~~	~~8.07~~	~~16.14~~ 47°		
	08	.81	0	10.13	20.26	•	
		.82	0		20.50	0	
		.82	0				

Apr. 20. 1931.

Reverse Solutions

$6.14 \frac{0.06}{0.02} = 2.045$

Chart	k.	L.R.	θ final	θ start	$\dot{\theta}$ average	$\dot{\theta}$ turns.	θ_0	θ_0.
	0.02.	~~.278~~						
19.	↓	.26 ✓	147.5	146	13	26 ✓	27.0	339
		.24 ✓	149.5	148	12	24 ✓	48.6	310
		.22 ✓	151.5	150	11	22 ✓	65	290
		.20 ✓	153.+	151.5	10	20 ✓	77.5	274
		.18 ✓	155.5	154.0	9	18 ✓	84	258
		.17 ✓		155.0		17 ✓	94	249
		.16 ✓	158	156.5	8	16 ✓	99	240
		~~.15~~	~~159~~	~~157.5~~	~~7.5~~	~~15~~		
		.14 ✓	160	158.6	7	14 ✓	108	220
		.13	161.5	160.0	6.5	13.		

Forward solutions.

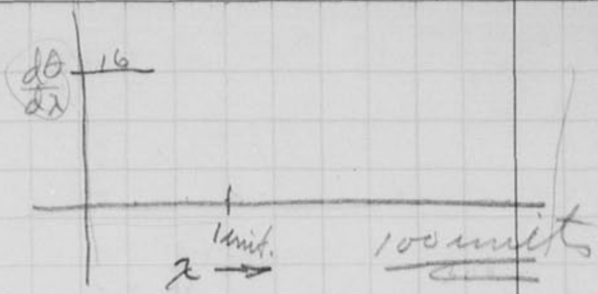
$6.14 \frac{1}{.6} = 10.23$

			$\dot{\theta}$	turns	θ_0		
20.	0.10	0.91	9.1	18.2	0	●	12°
		.92	9.2	18.4	0	●	8°
						critical	93.5
	.10	.94	9.4	18.8	0	○	just
apr 21.	.10	.8	8.0	16.0	180	○	just.
	.10	.79	7.9	15.8	180	●	just! 1° to go.

$\frac{d\theta}{d\lambda} = 16$ units

$D = 64$ rev/unit.

$\frac{64}{400}$ =



$100 \times 64 = 6400$ rev.

$\frac{6400}{\cancel{20}} =$ inch $= \cancel{20}^2$

$\frac{64 \text{ rev unit}}{16} = 4$ rev/unit.

$= \frac{4}{20}$ inch/unit, ?

$= \frac{1}{5}$ in/unit

or 5 units/inch

$n = \frac{400}{6400} = \frac{1}{16}.$

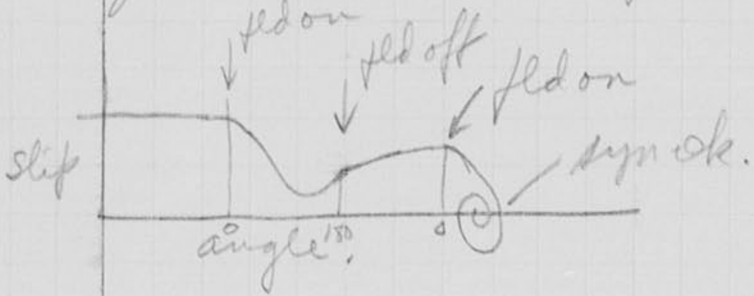
Results against time.

$6.14 \times \frac{4}{6} = 4.095$

k	L.R.	θ_0	$\dot{\theta}_{avg}$	turns,		
.04	.31	180	7.75	15.5	o	
.04	.30	180	7.5	15.0	o	
	.29	180	7.25	14.5	•	14°
.04	.48	0	12	24	•	8°

~~April~~ May 1, 1931. Pulling into step with intermittant field current.

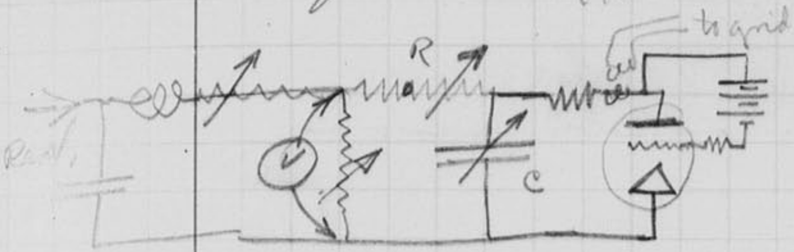
If the exciter is connected only when the field is such as to give motor action it might be possible to pull into step heavier loads. The stroboscopic relay can be arranged so that the field circuit is energized only when the angle lies between 0 and 180 electrical degrees. Then if a motor fails to pull in on the first swing, it ~~may~~ will not be driven further from synchronism when the angle is such as to give generator action since the field will be opened then.



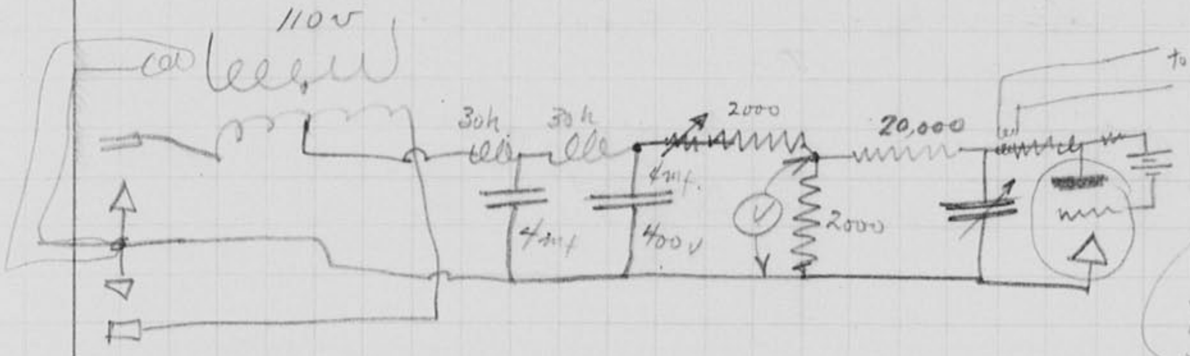
As shown in the figure the field first goes on, then if the motor fails to pull in and reaches 180° elect. degrees the field will be taken off and the motor will start to gain its initial slip. However again at 0 degrees the field is connected to the exciter and the motor again tries to pull in from a smaller slip.

Thyratron Oscillator for driving stroboscope grids

May 3, 1931.
H E Edgerton



the frequency is determined by the R and the C of the charging circuit x ~~...~~ and by the bias voltage one the grid.



$e_g = 10-150$ volts. negative with respect to the plate.

$200 \times .63 = 126.$ volts

$RC = 1/60 \text{ sec} = 0.0167 = 20{,}000\,C$

$$C = \frac{.0167}{.20{,}000} = \frac{1.67\times10^{-2}}{2.\times10^{4}} = .8 \times 10^{-6} = .8 \text{ mf.}$$

Or make R = 100,000 ohms.

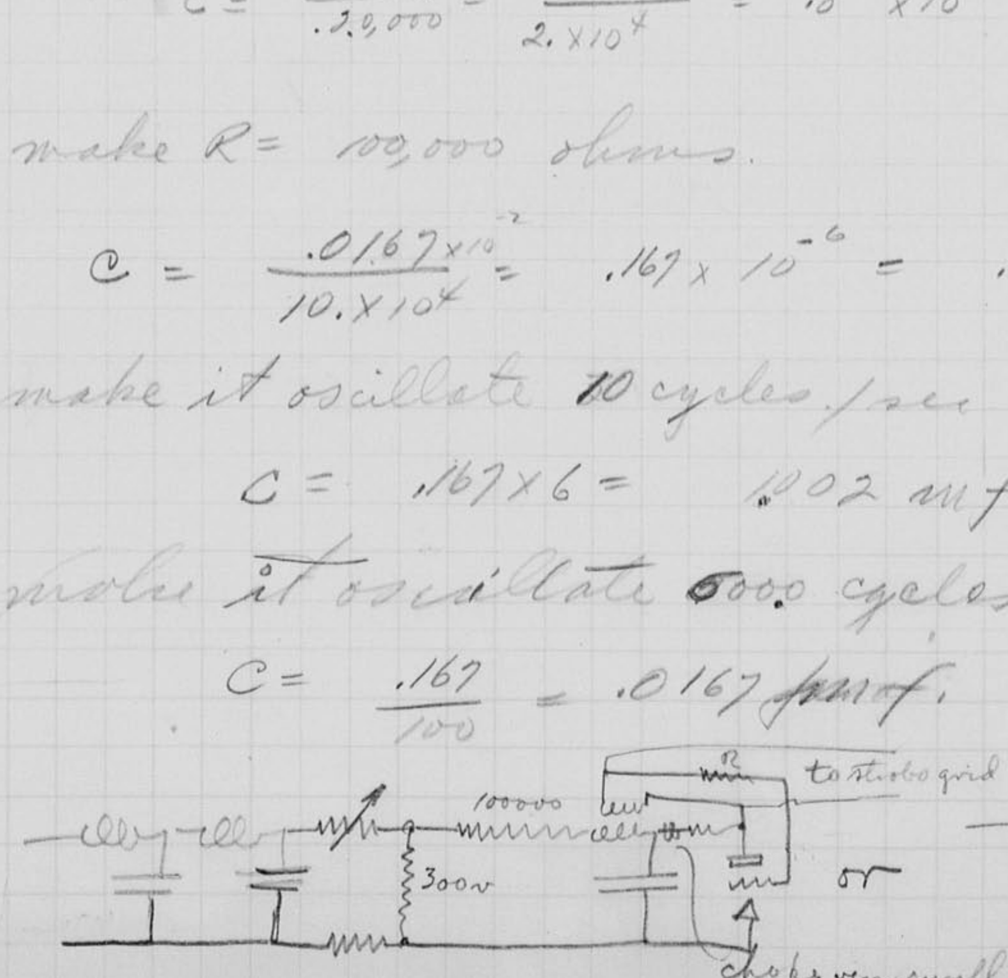
$$C = \frac{.0167\times10^{-2}}{10.\times10^{4}} = .167\times10^{-6} = .167 \text{ mf.}$$

to make it oscillate 10 cycles/sec

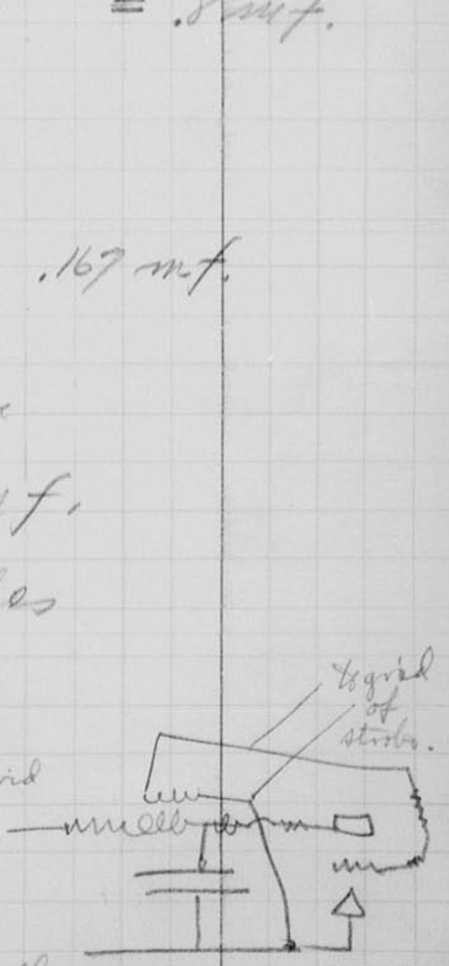
$$C = .167\times6 = 1.002 \text{ mf.}$$

to make it oscillate 6000 cycles

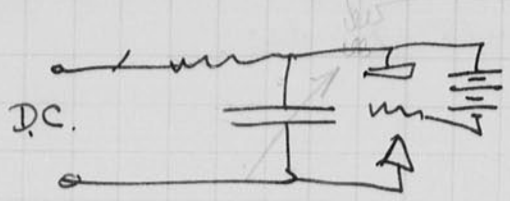
$$C = \frac{.167}{100} = .0167 \text{ mf.}$$

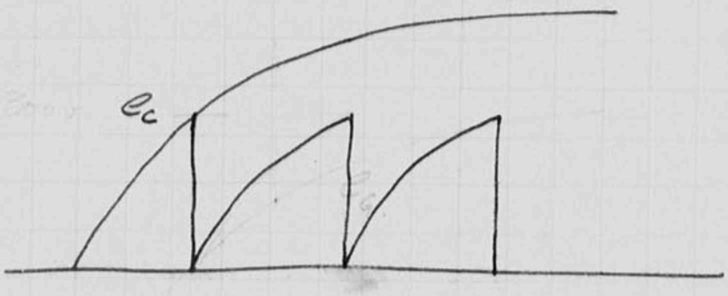


or



Witnessed May 3, 1931
[signature]

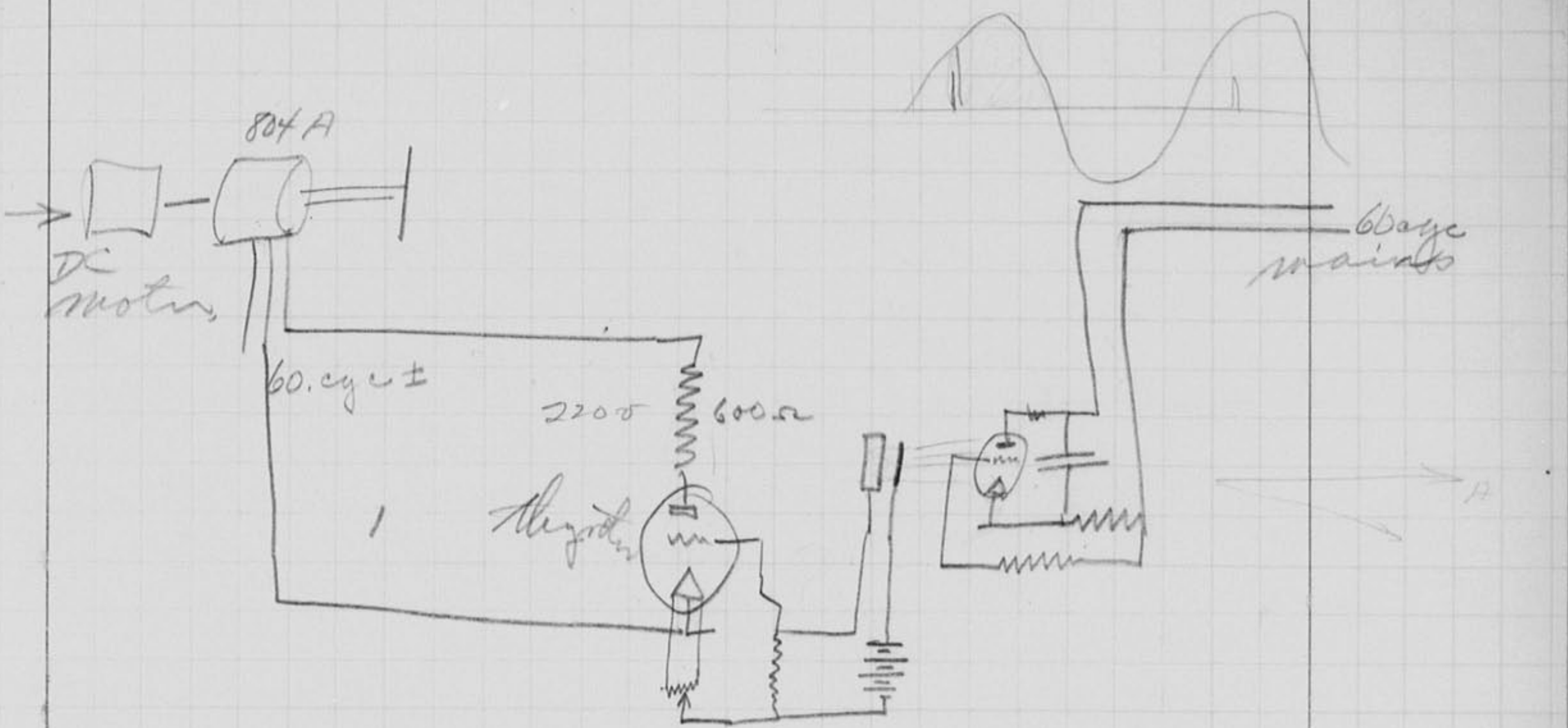

D.C.


e_c

May 5 1931

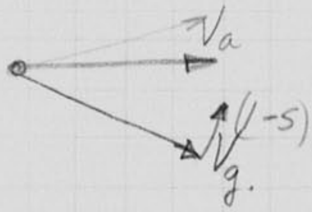
A. E. Edgerton
J. S. Gray.

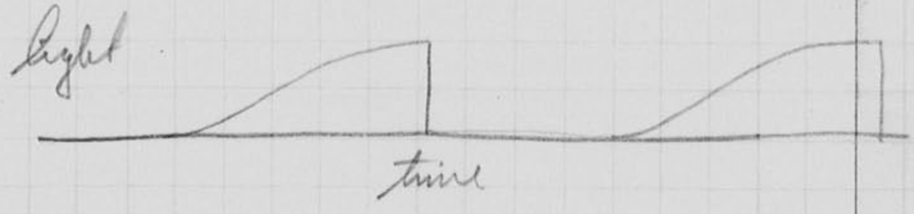
Photocell operation with Stroboscopic Light.



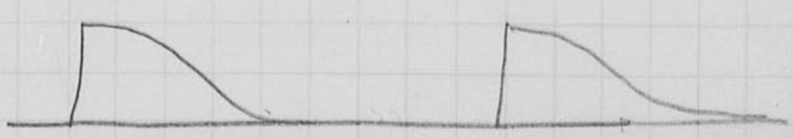
The light from the thyratron operated at a frequency which was the beat of the two frequencies

When the frequency of 804 A (alternator) was less than the mains the ~~frequen~~ light gradually increased to a maximum and then snaped off.





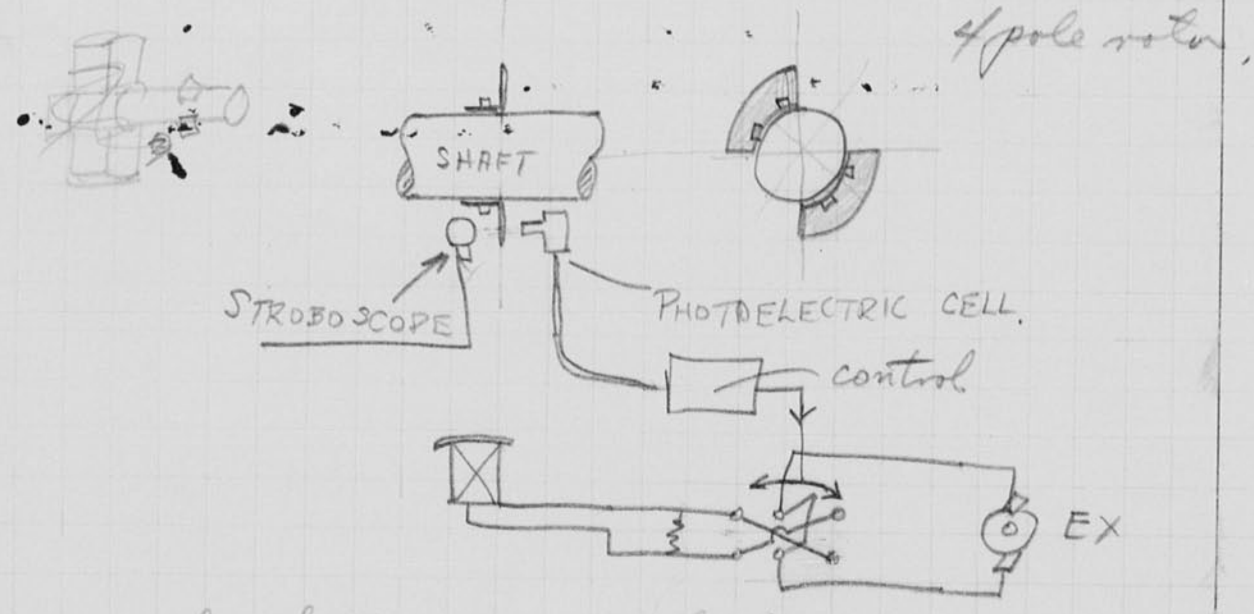
With the frequency of 804 A greater than the mains the variation of the light is the opposite



Field Switching Scheme.

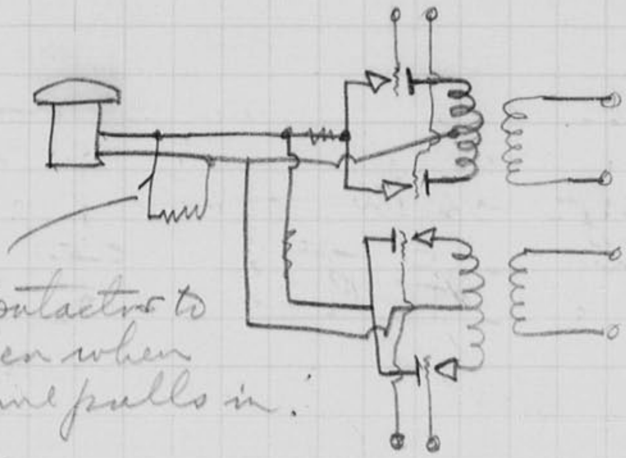
May 5 1931
V. Gaspertian

I propose to switch a synchronous motor field so that ~~it is always in such~~ the current in it is always in a sense as to give motor action. This can be accomplished by arranging a stroboscopic light opposite an obstruction driven by the rotor which is ~~in half of the time~~ in ~~the~~ path of the stroboscopic light from ~~the~~ to a photoelectric cell. The phase of the obstruction will be so arranged that it will allow the stroboscopic light to strike the photocell only when the angular displacement is between zero and 180 electrical degrees.



The field is connected one way when the stroboscopic light hits the ~~relay~~ photocell and is the other when the light is obstructed.

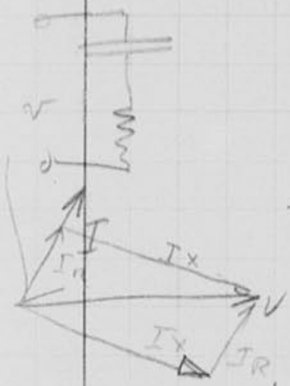
Cont.



Contactor to open when machine pulls in.

These can be one transformer.

Photocell and amplifiers are arranged to connect ~~the proper rectifier to the field to make it give motor action.~~



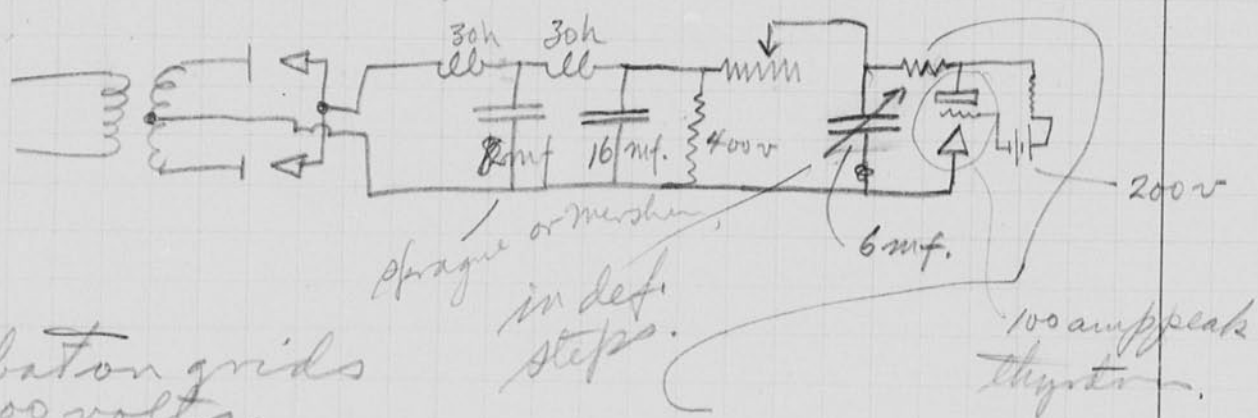
This circuit was shown to me on May 5, 1931 by H. E. Edgerton at Mass. Inst. of Technology, Cambridge, Mass.

Charles Kingsley Jr.

Witnessed May 13, 1931 E. L. Bowles

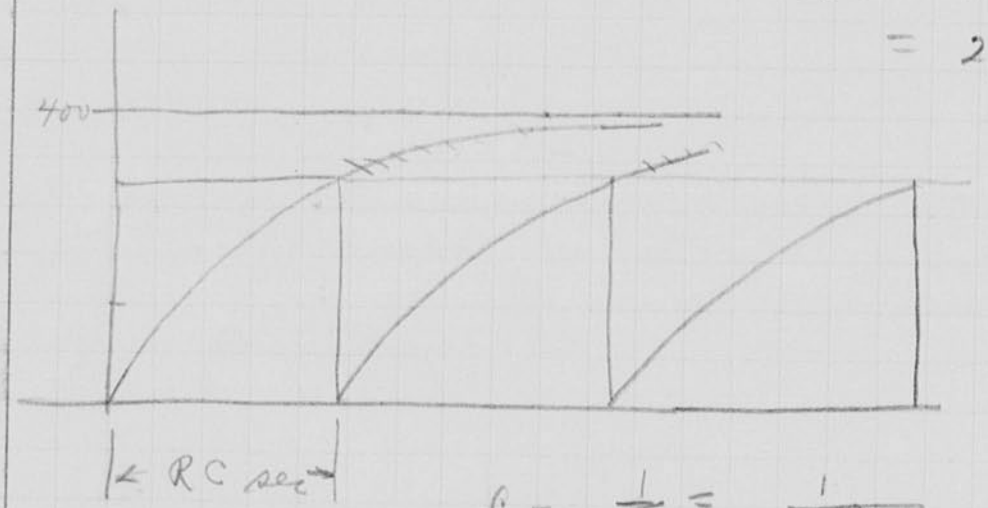
May 6, 1931.
H. E. Edgerton.

A-C operated variable frequency Stroboscope.



Cbaton grids
300 volts.

$\frac{400}{100} = 4$ ohms,
$RC = 4 \times 6 \times 10^{-6}$
$= 24$ ms.



$f = \frac{1}{RC} = \frac{1}{R \times 10^{-6} \times 6}$

$300 \overline{)1,000,000.}$ 3000.

$60 = \frac{1}{R \times 6 \times 10^{-6}}$

$R = \frac{60}{6 \times 10^{-6}} = 10 \times 10^{6}$ ohms.

~~$RC = 6 \times 10^{-6} \times 10 \times 10^{6} = 60$ sec~~

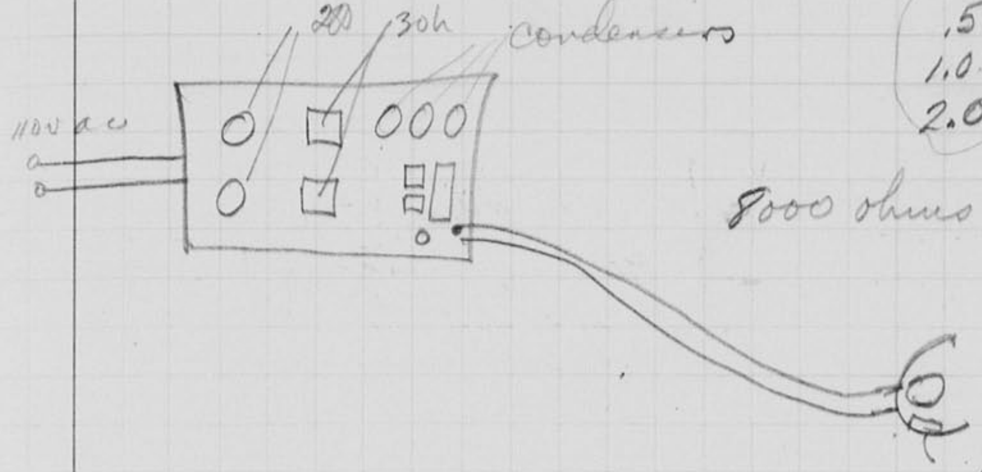
$\frac{1}{60} = RC \qquad R = \frac{1}{60 \times 6 \times 10^{-6}} = \frac{10^6}{360} = 3000$ ohms.

try 2 mf. for discharge and 4 ohms in disc. circuit

$R = \frac{1}{60 \times 2 \times 10^{-6}} = \frac{10^6}{120} = 10{,}000$ ohms.

5,000 – 30,000 ohms. chg circuit
0.5 to 4 mf. condenser

Cont



.25
.5
1.0
2.0

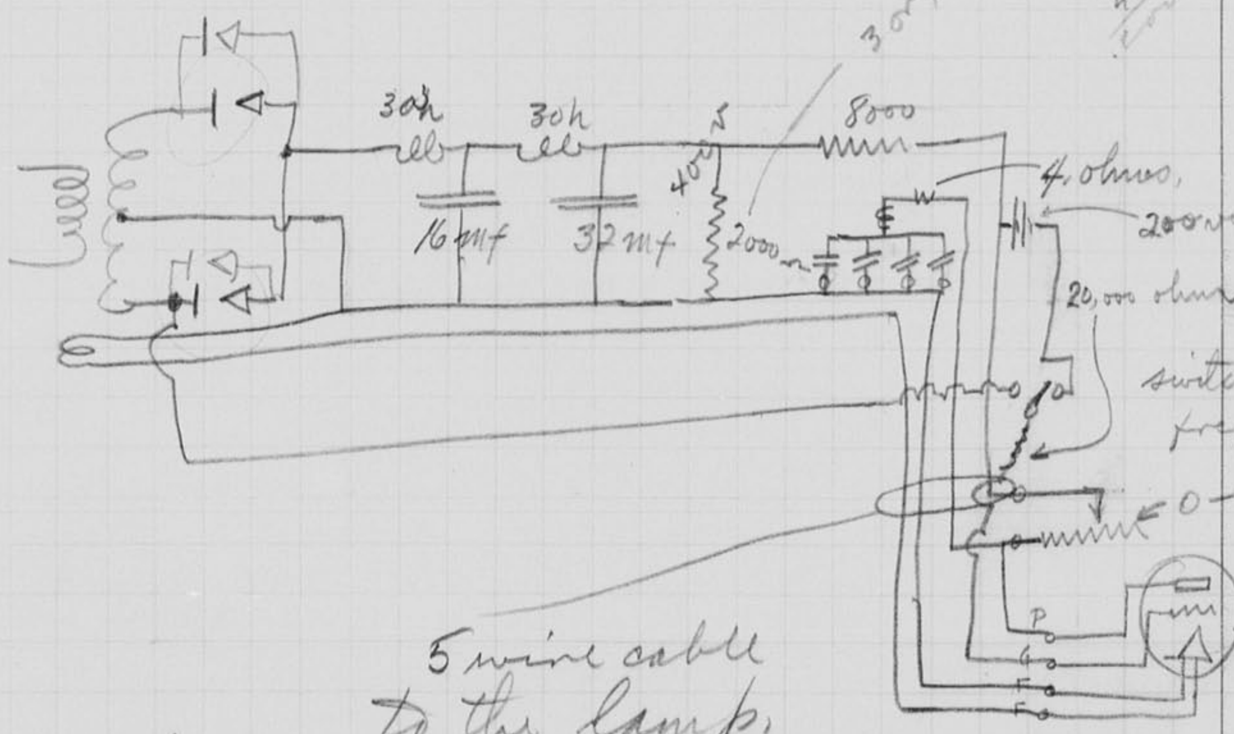
8000 ohms — 20,000.

80 / 400

15000 ohm resistance.

$25 = \frac{50}{2}$ ma. rating

200 ma.



5 wire cable
to the lamp.

The resistor in the hood gives freq control right there where the light is.

$.25 \times 10^{-6} \times 8000 = .002000 \times 10^{-6} = .002$ sec

$\frac{1}{.002} =$ 500 cycles. max freq. $500 \times 60 = 30{,}000$

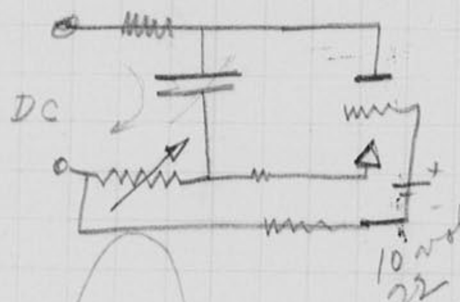
100 amp peak.

$3.75 \times 23{,}000 \times 10^{-6} = .090{,}000$ r.p.m.

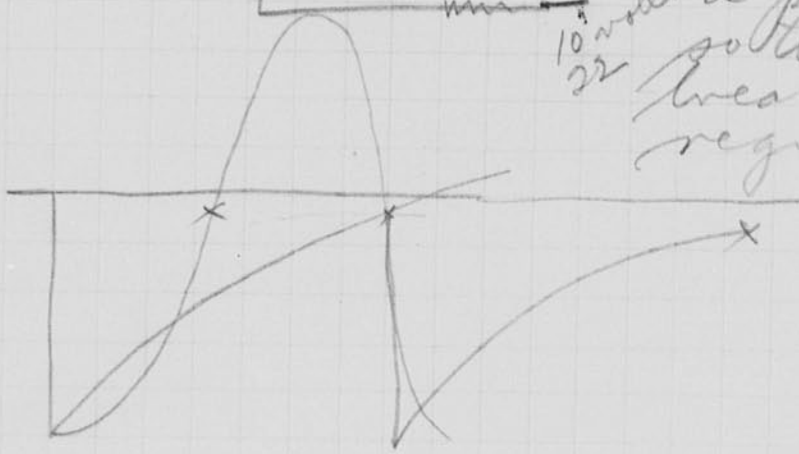
$\frac{1}{.09} =$ ~~1~~0 cyc. 660

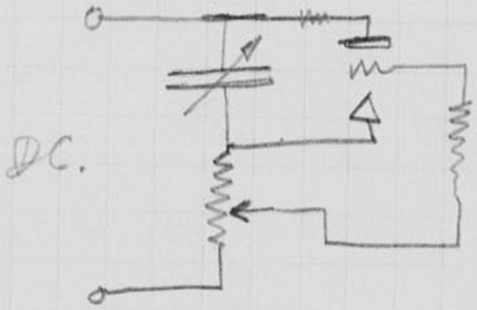
range

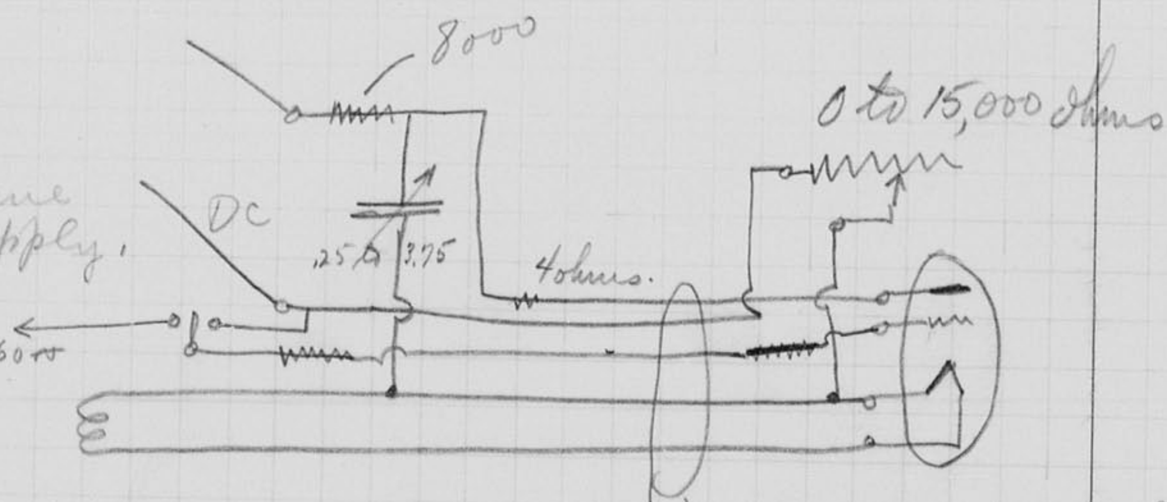
Cont,



This eliminate the ~~c battery~~ large c battery but will require a positive c bias so the tube will break down regularily.





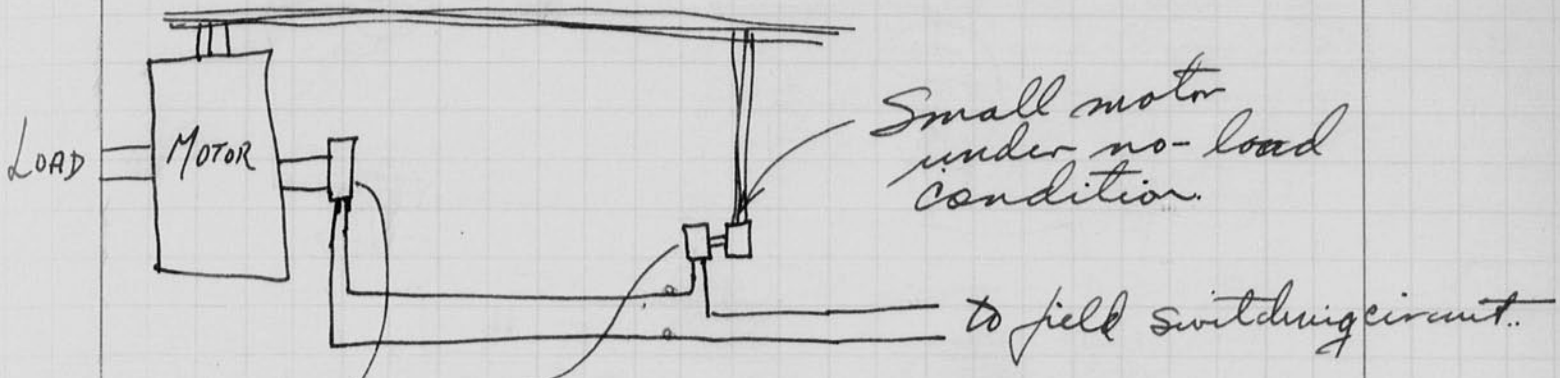


Same B supply.

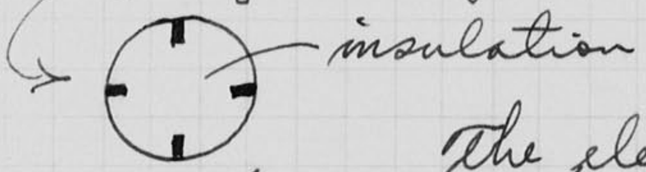
Witnessed
T. C. Hay
May 6, 1931
J. L. Boosler
May 12, 31

5 conductor cable

May 14 1931 Field Switching Scheme for a
H. E. Edgerton Synchronous Motor.



Commutator to have one ~~seg~~ segment for each pair of poles.

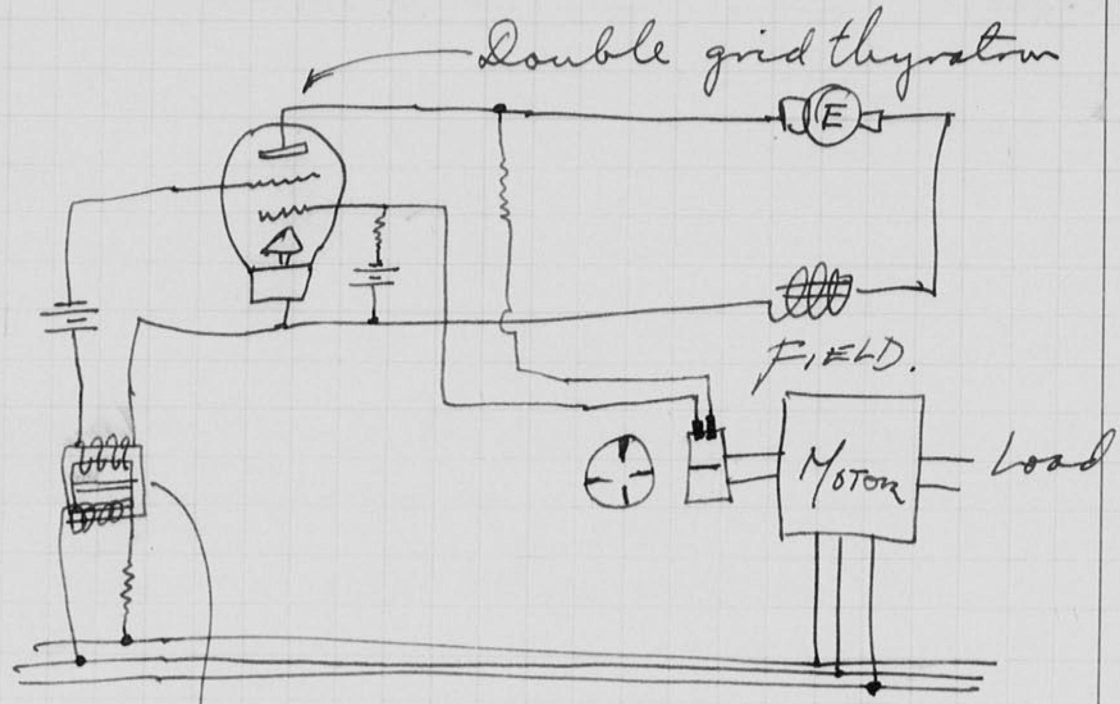


The electrical circuit through the field switching arrangement is only made when the two sets ~~of brushes~~ ~~commutators~~ are ~~on their~~ both on their respective commutators segments at the same time.

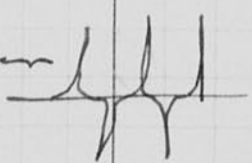
One disadvantage of this scheme is that the electrical contact is not made very long and so the ~~impulse~~ impulse to the trip circuit needs to be amplified by some sort of sensitive relay.

An advantage of this scheme is that the small synchronous motor ~~need only to~~ does not need to be lined up with the big motor and can be placed anywhere on the control board, etc.

Cont. Field Switching Schemes.



Saturated core transformer to give a peaked voltage.



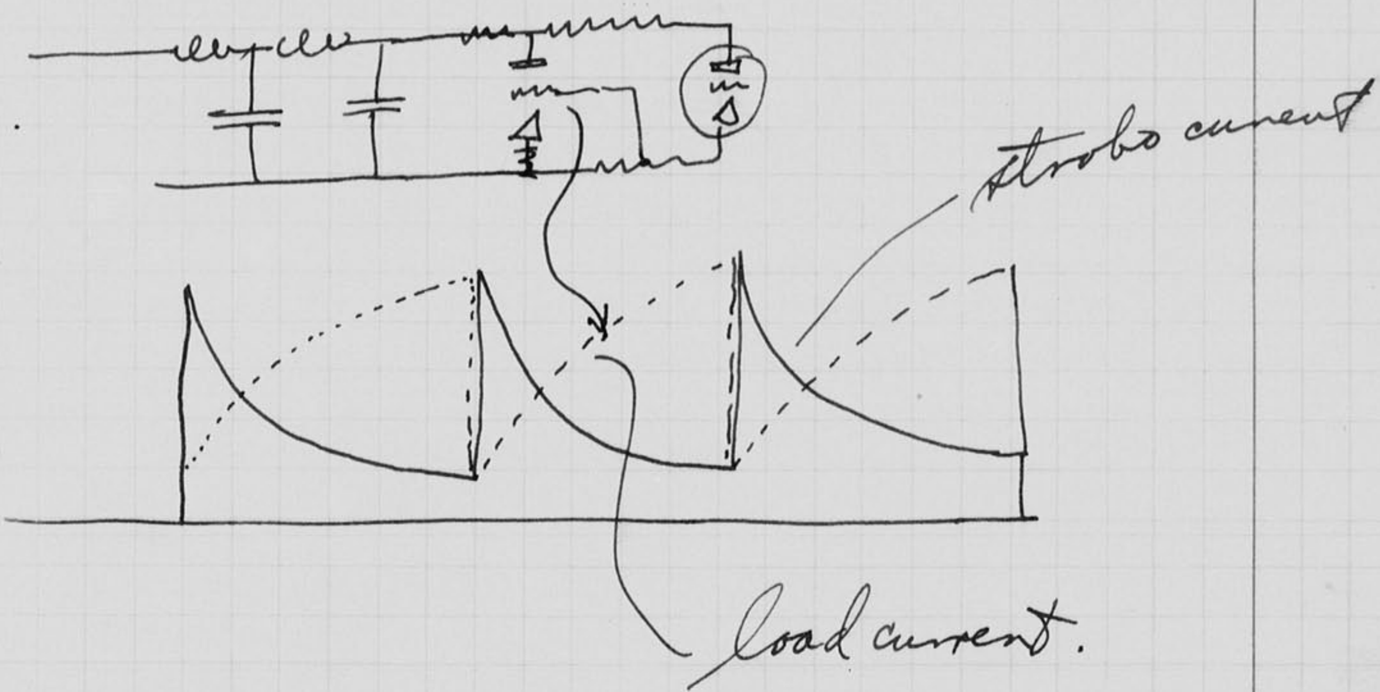
The thyratron will not conduct until the two grids are positive. This only occurs when the angular displacement has a certain phase relationship ~~to the~~ which is adjusted so that it occurs at the most favorable switching angle, that is, zero degrees.

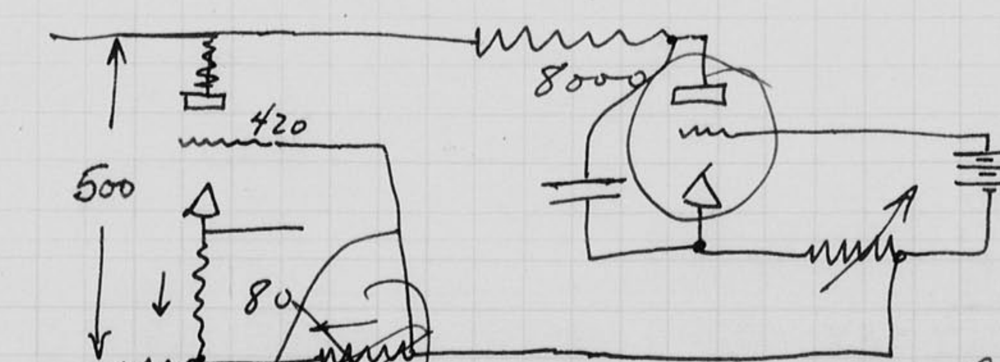
It would be more accurate to say that the thyratron does not conduct until there is a certain relationship between the potentials on the two grids. ~~It~~ the necessary voltages to cause breakdown may be either positive or slightly negative.

May 16 1931
H E Edgerton

Constancy of the frequency of the stroboscope shown on pages 88-90 depend upon a constant d-c voltage. One method to get this is to have a large enough "B" eliminator so that the load current does not appreciably change the voltage.

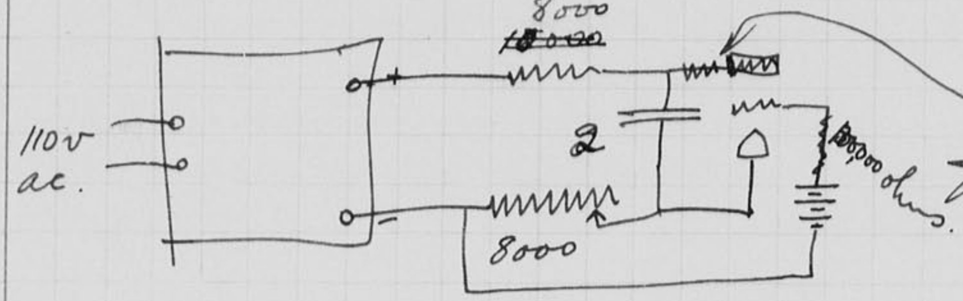
A load just like the stroboscope but arranged so that the sum of the current is constant may help to keep the frequency constant.





Bias ~~increased~~ ~~decreased~~ increased by charging current to the condenser.

Cont. Scheme to be tried.



$\frac{500}{x} = 25$ $x = \frac{~~200~~}{25}$ 20

4×5

Sugr. = 50 ohms. to limit current.

$RC = \frac{1}{60}$ sec.

$C = 2\times10^{-6}$ $R = \frac{10^6}{60\times2} = \frac{10^{4}}{1.2\times10^{2}}$

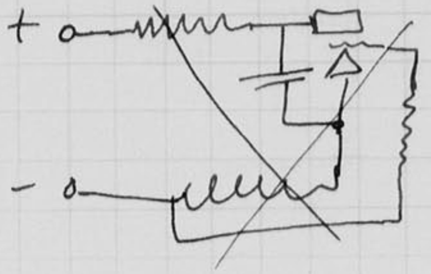
$= 10,000$ ohms.

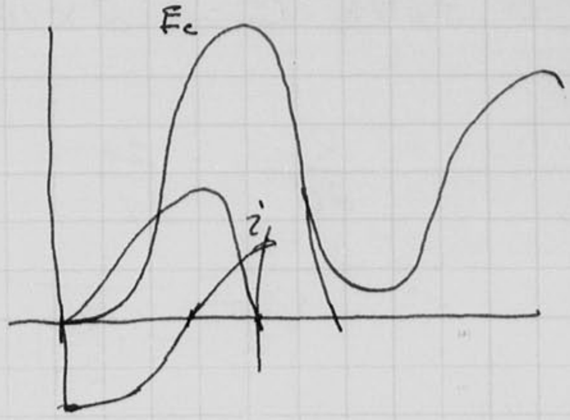
~~Material list for strobo.~~

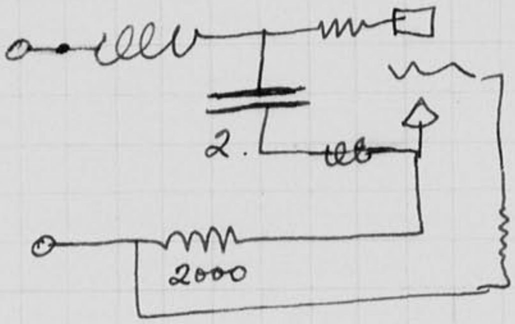
2 mf good for 100 v. d.c. .25 to 2 mf steps.
1 – 8000 ohms
1 – 8000 ohms slide.
1 – 100,000 ohms
1 – "B" battery 22 volts.
1 – 50 ohm slide wire.

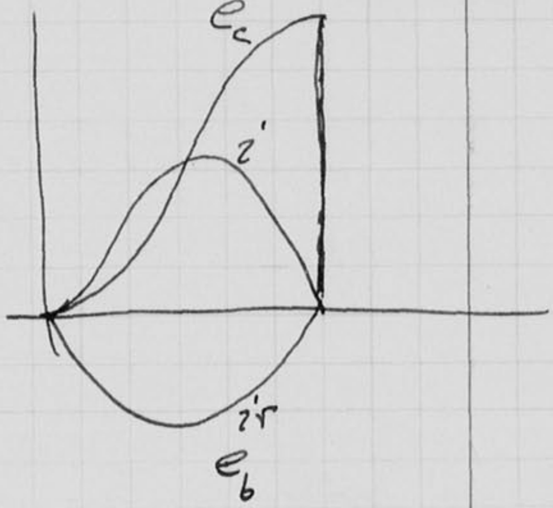
FG-27 and fil. transformer.

Cont.









$$\frac{1}{2\pi\sqrt{LC}} = f$$

$$T = 2\pi\sqrt{LC}$$

$$\frac{1}{60} = 2\pi\sqrt{2\times L}$$

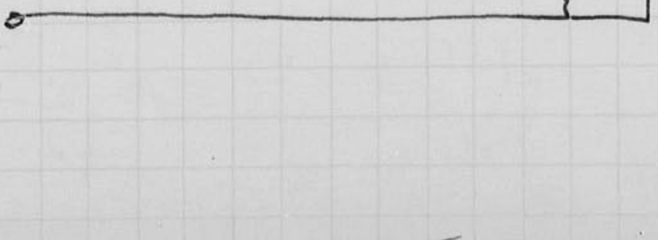
$$\frac{1}{3600} = 4\pi^2\, 2\times L.$$

$$L = \frac{1}{3600 \cdot 4\pi^2 \, 2\times 10^{-6}} = \frac{1}{.288\times \cancel{10^{-6}}}$$

$10 \quad 8$

.288,000.

$$= \frac{1}{.288} = .347\,h.$$



$$\alpha = \frac{R}{2L} \qquad \frac{L}{R} = \frac{.347}{2000} =$$

$$\alpha = \frac{2000}{2 \cdot .347} = 3000$$

$L = .347h \quad C = 2 \times 10^{-6} f \quad R = 2000$

R.

$$\frac{R}{2L} = \frac{2000}{2 \times .347} \cong 3000$$

$$\cancel{\frac{R}{\sqrt{\frac{L}{C}}} = .268.}$$

$$\cancel{\sqrt{\frac{1}{LC} - \left(\frac{R}{2L}\right)^2} = \sqrt{1.43 \times 10^6 - 10 \times 10^6}}$$

$$\frac{1}{LC} = \frac{1}{.347}\,\frac{1}{2 \times 10^{-6}} = \frac{10^6}{.7} = 1.43 \times 10^6$$

3000
3000
$10,000,000$

3.000
10×10^6

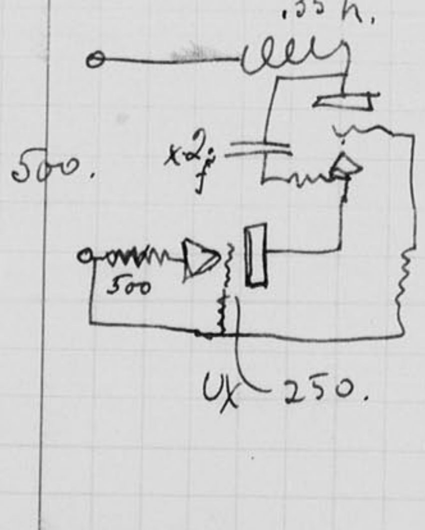
the circuit is over damped.

R must be less than

$$\left(\frac{R}{2L}\right)^2 < 1.43 \times 10^6$$

$$\frac{R}{2L} < 1.2 \times 10^3 = 1200$$

$$R = 2400 \cdot .35 = 840 \text{ ohms.}$$



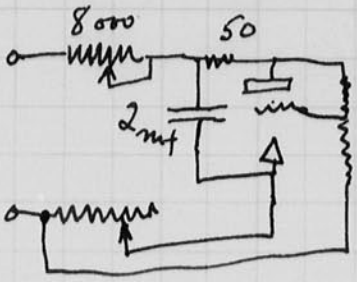
~~too~~ complicated!?

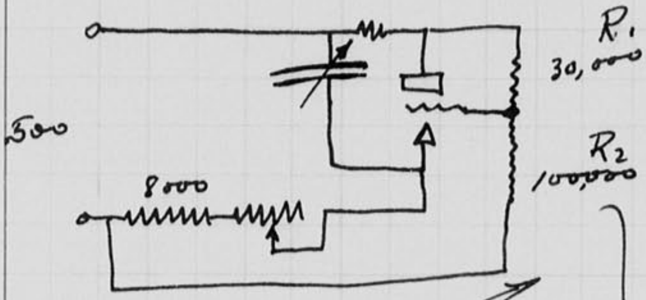
$10\, mf \times 20 = 200\, m.s.$

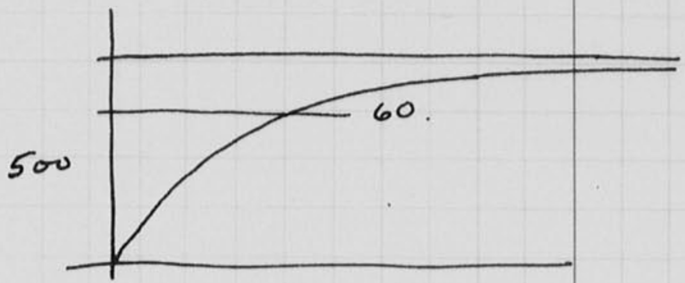
$$\frac{0.800}{\sqrt[3]{\frac{.35}{2.}}} = 2.$$

$\sqrt{.17} = .41$

May 19 1931
H E Edgerton.

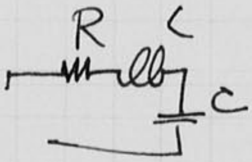


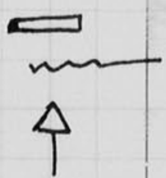




make $\frac{R_2}{R_1} = 3.$ approx.

this makes the grid go positive ~~before the con~~ as soon as the condenser has built up to 60 % of ~~its final va~~ the final value it would have if the tube did not strike.





$$L\frac{d^2q}{dt^2} + R\frac{dq}{dt} + \frac{1}{C}q = \cancel{E} = E1.$$

Let $t = a\lambda$.

$$\frac{a^2 d^2 q}{a^2 d\lambda^2} + \frac{a^2 R}{aL}\frac{dq}{d\lambda} + \frac{a^2}{LC}q = a^2\frac{E}{L}1.$$

$$\left(\rho^2 + a\frac{R}{L}\rho + \frac{a^2}{LC}\right)q = a^2\frac{E}{L}1. \qquad \rho = \frac{d}{d\lambda}.$$

Let $\frac{a^2}{LC} = 1 \qquad a = \sqrt{LC}$

$$\left(\rho^2 + \frac{R\sqrt{LC}}{L} + \frac{(\sqrt{LC})^2}{LC}\right)q = \cancel{L}C\frac{E}{\cancel{L}}1.$$

$$\left(\rho^2 + \frac{R}{\sqrt{\frac{L}{C}}}\rho + 1\right)q = EC1.$$

$$\left(p^2 + \frac{R}{\sqrt{\frac{L}{C}}}\,p + 1\right) = 0 \quad \text{~~for~~ roots.}$$

$$p = -\frac{R}{2\sqrt{\frac{L}{C}}} \pm j\sqrt{1 - \left(\frac{R}{2\sqrt{\frac{L}{C}}}\right)^2}$$

critically damped case

$$\frac{R}{2\sqrt{\frac{L}{C}}} = 1. \qquad R = 2\sqrt{\frac{L}{C}}. \qquad \sqrt{.17} = .41$$

$$= 2\sqrt{\frac{.35}{2\times 10^{-6}}}$$

$$= 2\times 10^3 \times \sqrt{\frac{.35}{2}} = .8\times 10^3 = 800 \text{ ohms.}$$

~~In a similar manner~~ the current ~~instead~~ of the charge.

$$\left(\frac{dL}{dt} + R + \frac{1}{C}\int dt\right) i = E\,1.$$

Let $t = a\lambda$.

$$\left(\frac{dL}{a\,d\lambda} + R + \frac{a}{C}\int_0 d\lambda\right) i = E\,1.$$

$$\left(\frac{d}{d\lambda} + \frac{Ra}{L} + \frac{a^2}{LC}\int d\lambda\right) i = a\frac{E}{L}\,1.$$

$$a^2 = LC. \quad p = \frac{d}{d\lambda}.$$

$$\left(p + \frac{R}{\sqrt{\frac{L}{C}}} + \frac{1}{p}\right) i = \frac{E}{\sqrt{\frac{L}{C}}}\,1.$$

$$\left(p^2 + p\frac{R}{\sqrt{\frac{L}{C}}} + 1\right) i = p\,\frac{E}{\sqrt{\frac{L}{C}}}\,1.$$

$$i = \frac{p\,E/\sqrt{\frac{L}{C}}\;1}{\left(p^2 + p\,R/\sqrt{\frac{L}{C}} + 1\right)}$$

$$\frac{p}{(p^2+2\alpha p+\omega_0^2)}\,1 = \frac{\varepsilon^{-\alpha t}}{\omega}\sin\omega t\,1$$

$$\omega_0^2 > \alpha^2 = \omega_0^2 - \alpha^2$$

$$\tan\phi = \omega/\alpha$$

$$\cancel{\alpha = \frac{R}{2L}}$$

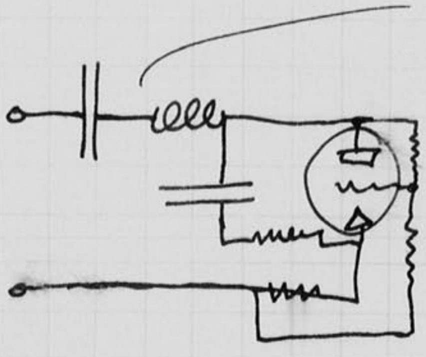
$$\alpha = \frac{R}{2\sqrt{\frac{L}{C}}}$$

$$i = \frac{E}{\sqrt{\frac{L}{C}}}\ \varepsilon^{-\alpha t}\sin(\lambda)\ 1$$

$i_{max} = 2E\sqrt{\frac{C}{L}}$ for $\alpha = 0$ no damping.

$L = .35 \quad C = 2\times 10^{-6} \qquad E = 500$

$$i_{max} = 2\times 500\sqrt{\frac{2\times10^{-6}}{.35}} = 1000\times 10^{-3}\overset{2.4}{\sqrt{5.7}} = 2.4\text{ amps.}$$



~~to~~ prevent shunting the tube if the grid fails.

$$\frac{Li^2}{2} = \frac{1225}{2} = 112 \text{ Joules.}$$

$$\frac{CE^2}{2} = 112$$

$$E = \frac{225}{10\times10^{-6}} = 22.0\times10^{6}\ \frac{\text{volts}}{2}.$$

10,000 cycles per sec.

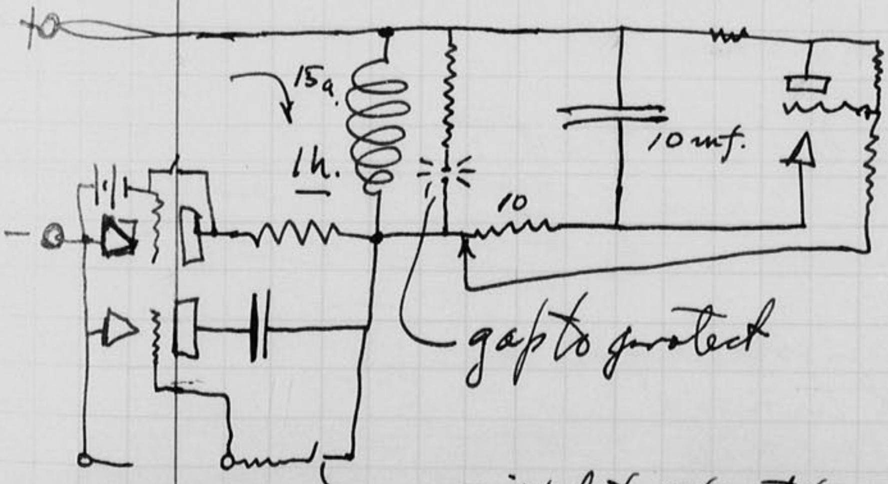
$\frac{1}{10000}$ sec per cycle.

1×10^{-4} sec. = time const

$1\times10^{-4} = 10\times10^{-6} R.$

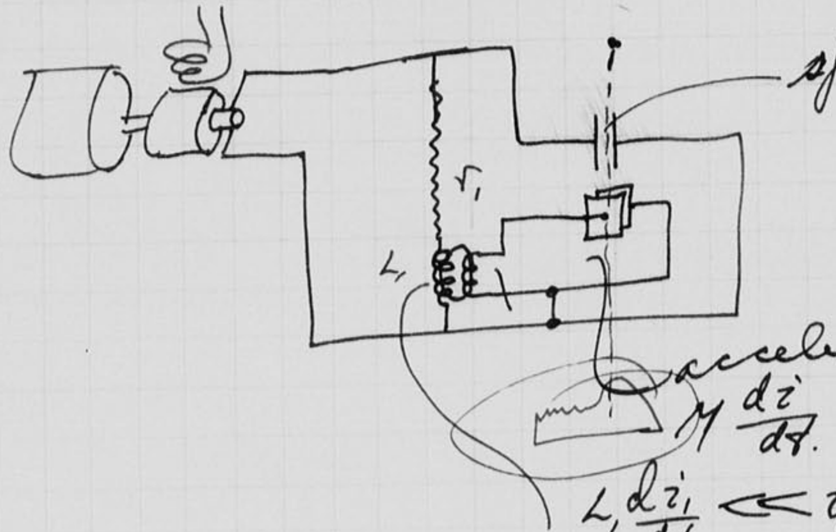
$$R = \frac{1\times10^{-4}}{10\times10^{-6}} = \frac{10^2}{10} = 10 \text{ ohms}$$

if tube flashes and discharge.



May 17 1931
H. E. Edgerton.

Speed - torque (acceleration) measurement by means of the cathode ray oscillograph.



$L_1\frac{di_1}{dt} \ll i_1 r_1$

I Ripple must be less than .5%

$M\frac{di}{dt}$ must give voltage enough to deflect beam.

say $\frac{.5 \text{ amp.}}{.1 \text{ sec}} = 5. \text{ am./sec} = \frac{di}{dt}$.

$100 \text{ volts} = M\frac{di}{dt}$

$M = \frac{100}{5} = 20.\ h.$ $\quad \frac{L_1}{L_2} : \left(\frac{N_1}{N_2}\right)^2$

$\frac{100}{.5} = 200$ ohms.

$L\frac{di}{dt} << 100$ say 1 volt.

$L = \frac{1}{5} = 0.2\ h.$ $\quad M = \sqrt{L_1 L_2}$

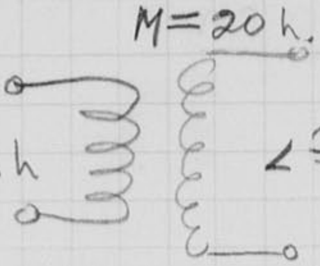
$L_2 = \frac{M^2}{L_1} = \frac{20 \cdot 20}{0.2} = \underline{\underline{4000.}}\ h.$ (200)

This transformer needs a very large ratio of turns.

$\left(\frac{N_2}{N_1}\right)^2 = \frac{4000}{0.2} = 20,000$

$\left(\frac{N_2}{N_1}\right) = 140.$ to 1 ratio.

50 turns.
7500 turns.



Ratio of trans
$\underline{\underline{150 \text{ to } 1}}$.

$L\frac{di}{dt} = j\omega L i$ for ac:
at 60 cycles. $377L \ll 200$ ohms.
say 2 ohms.

$$L = \frac{2}{377} = 0.053\ h.$$

if M needs to be from 15 to 100 h.

$\left(\frac{N_2}{N_1}\right)^2 = \sqrt{\frac{L_2}{L_1}}$ $\qquad M = \sqrt{L_1 L_2}$ unity coupling.

$$L_1 = \frac{M^2}{L_2}$$

$$\frac{N_2}{N_1} = \sqrt{\frac{L_2 L_2}{M^2}} = \sqrt{\frac{L_2^2}{M^2}} = \frac{L_2}{M} \qquad L_2 = \frac{M^2}{L_1}$$

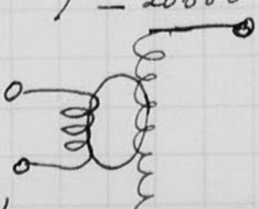
$$\frac{N_2}{N_1} = \sqrt{\frac{L_2}{L_1}} = \sqrt{\frac{M^2}{L_1^2}} = \frac{M}{L_1}$$

Let $M = 15$ $\quad L = 0.053$.

$$\frac{N_2}{N_1} = \frac{15 \times 372}{2} = 2800 \text{ to } 1.$$

$M = 100 \quad L = 0.053$.

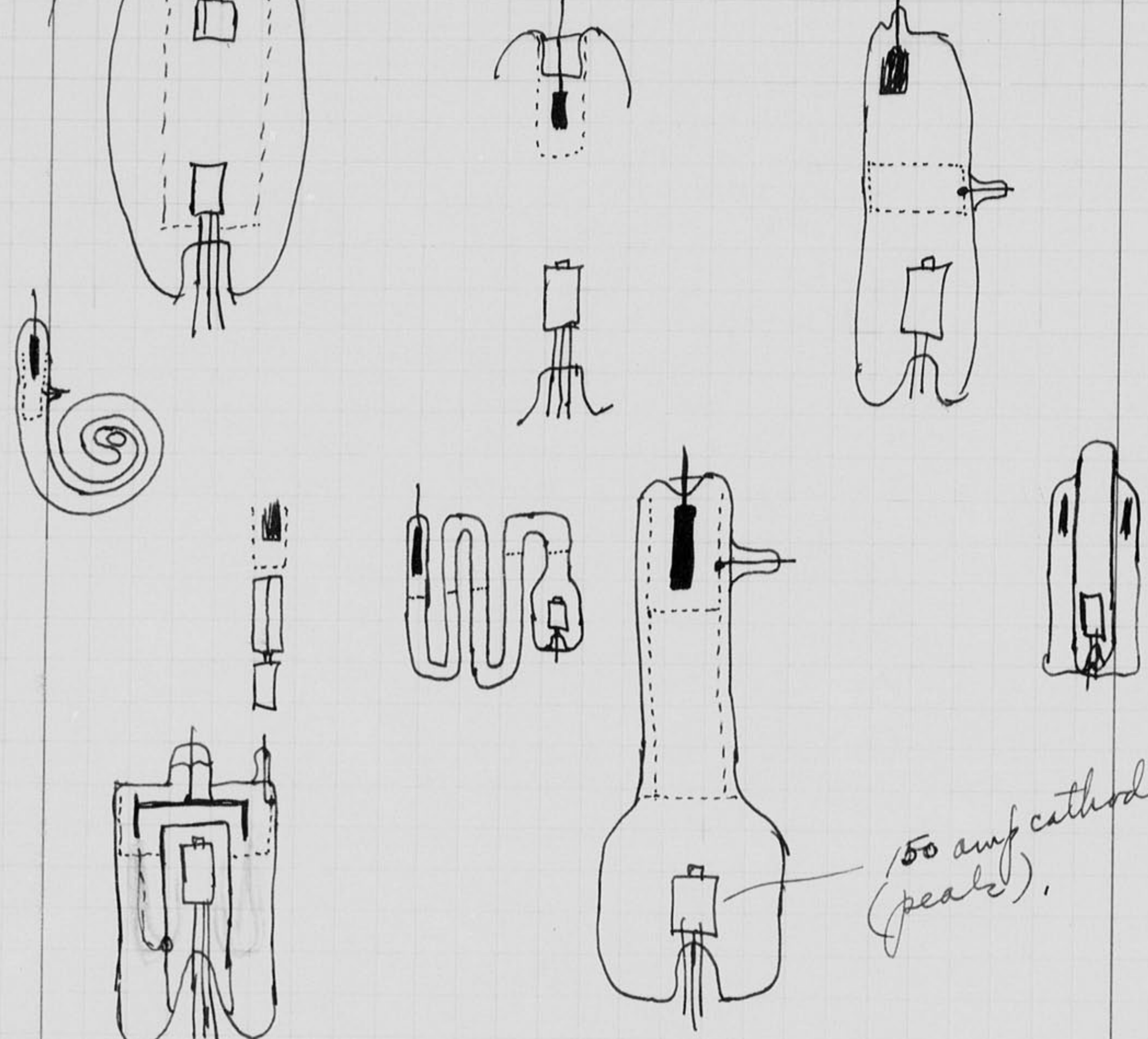
$$\frac{N_2}{N_1} = 100 \times \frac{372}{2} = 18{,}600 \text{ to } 1.$$

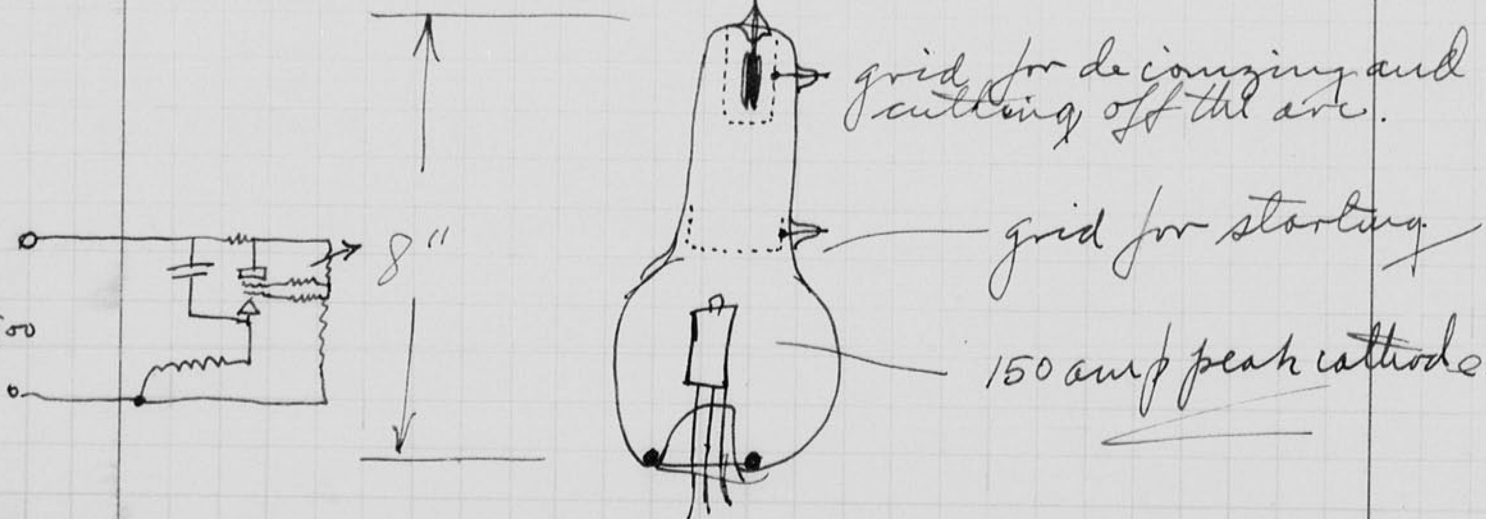


(0.5 amp dc.) no non-linear effects.

May 17 1931. Thyratron for light

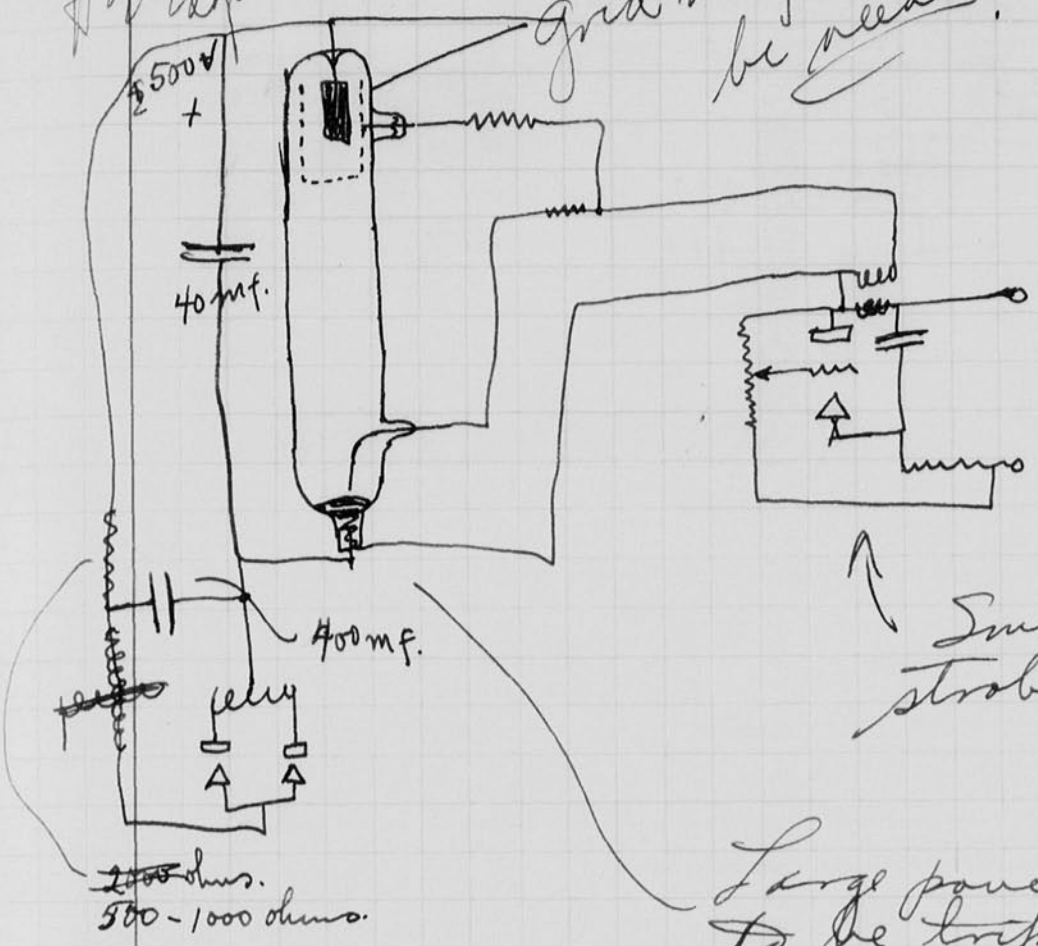
H. E. Edgerton





May 17 1931
H.E. Edgerton

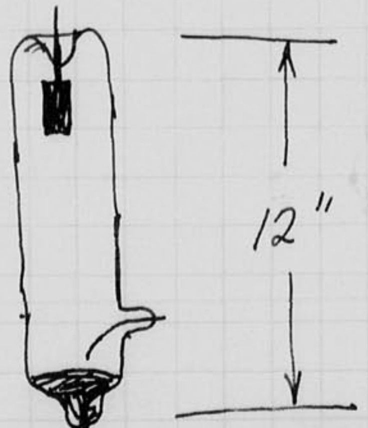
grid may not be ~~needed~~.



Small visual stroboscope.

Large powerful strobo to be tripped by the small one.

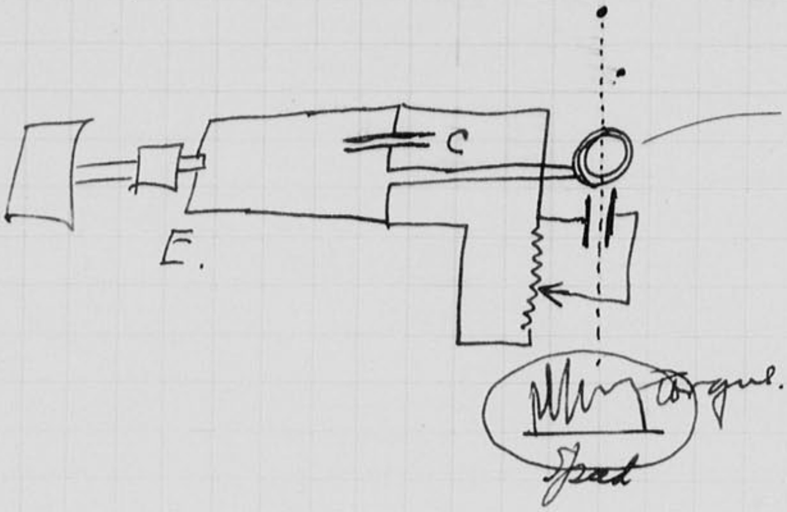
No holding spot needed. The discharge of the small strobo is put through a spark coil which forms a spot on the big tube's pool.



Wrap externally with wire and connect it to the starting anode.

May 18, 1931. Speed-torque Cathode ray tests.

S. Edgerton.

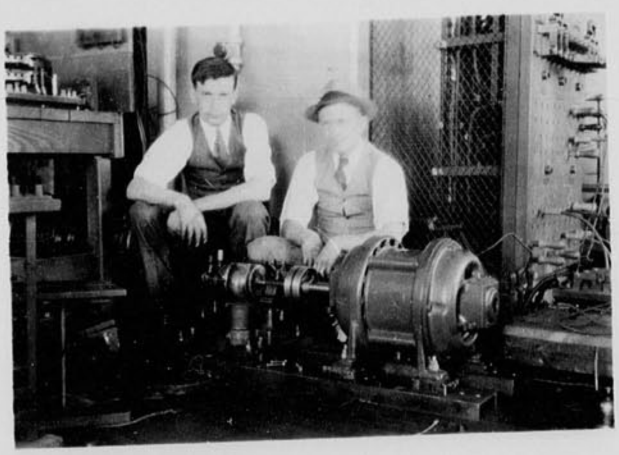


~~$L\frac{di}{dt} \ll C\frac{de}{dt}$~~

$Ri \ll C\frac{de}{dt}$ E.

$L\frac{di}{dt} \ll E.$

Jim Byrne



Dick Mason.

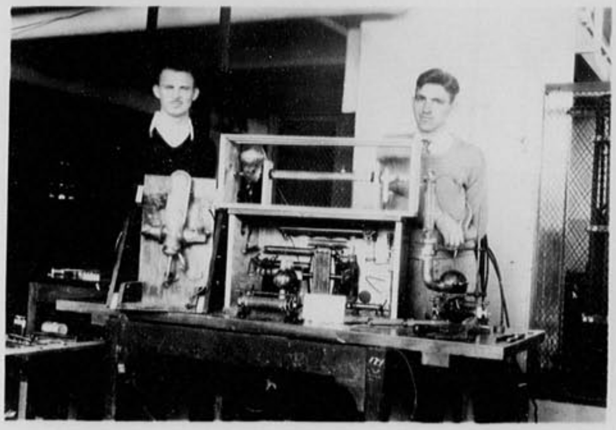
with pulsationless-free generator.

May 19 1931

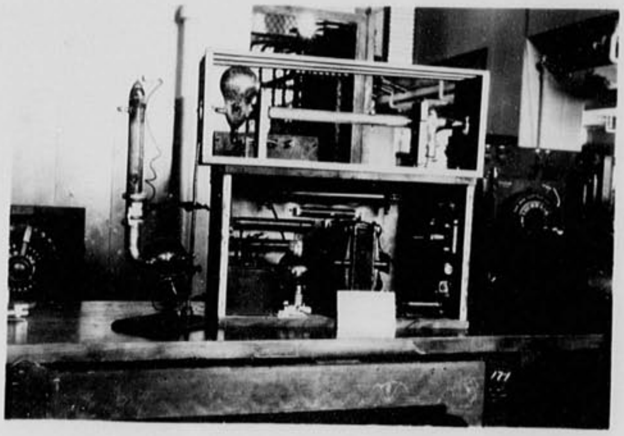
Photographs taken
May 19, 1931.

J. B. McClure

Lawrence M. Stauder

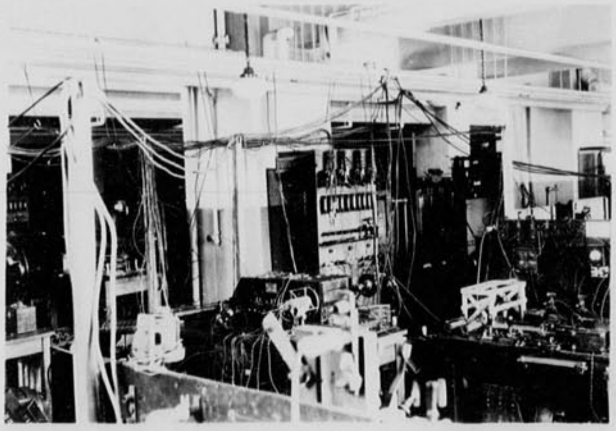


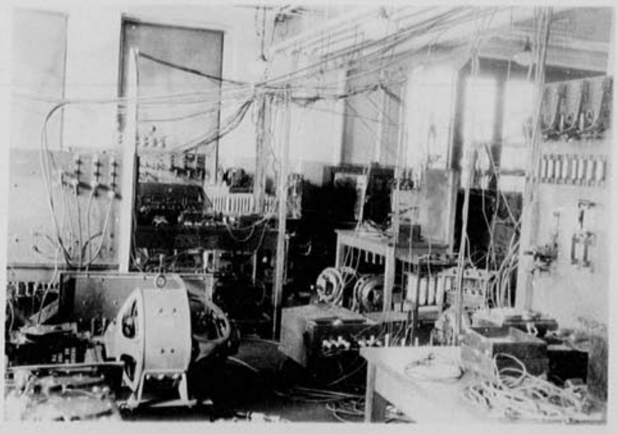
Stroboscope equipment



Machine transients Laboratory.

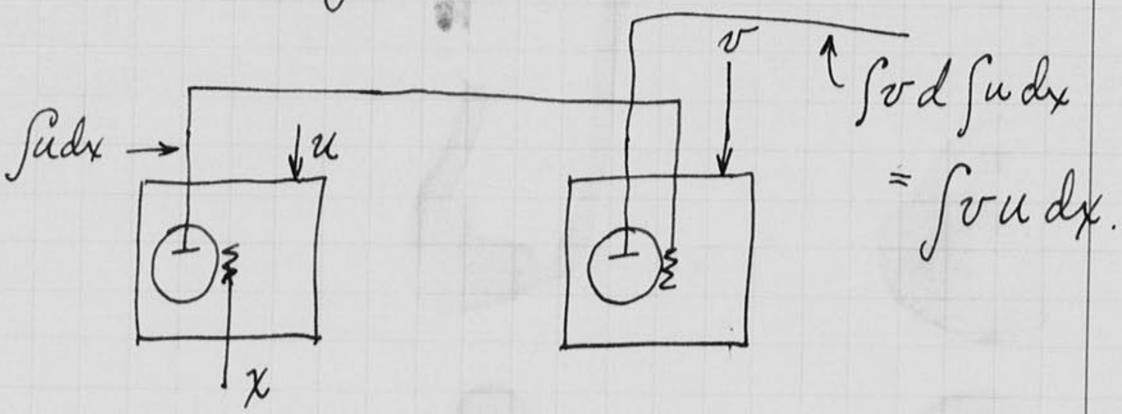
Spring 1931.



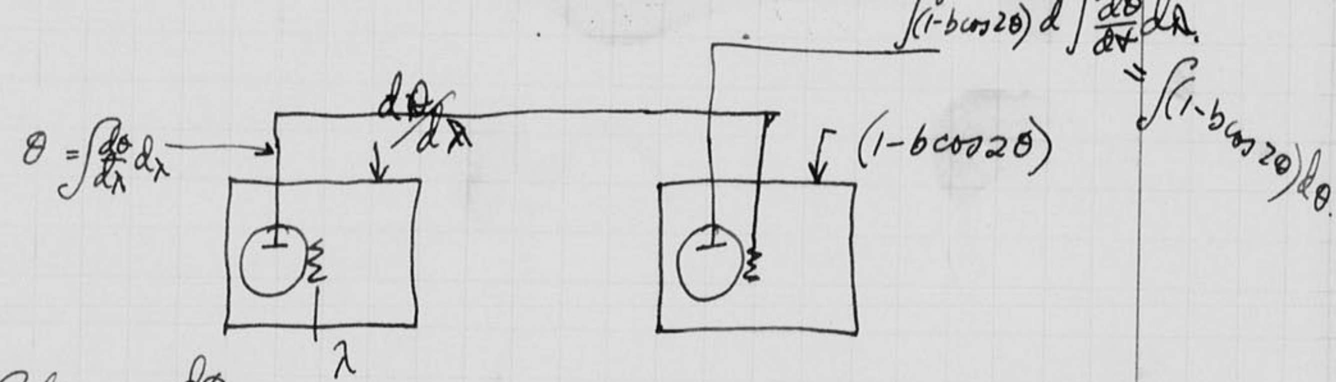


Method of Getting $\int uv\,dx$ on the Integraph.

$$\int uv\,dx.$$



In the ~~synchronous~~ machine problem the term $\int (1 - b\cos 2\theta)\frac{d\theta}{d\lambda}\,d\lambda$ can be solved in this manner.



Let $u = \frac{d\theta}{d\lambda}$.

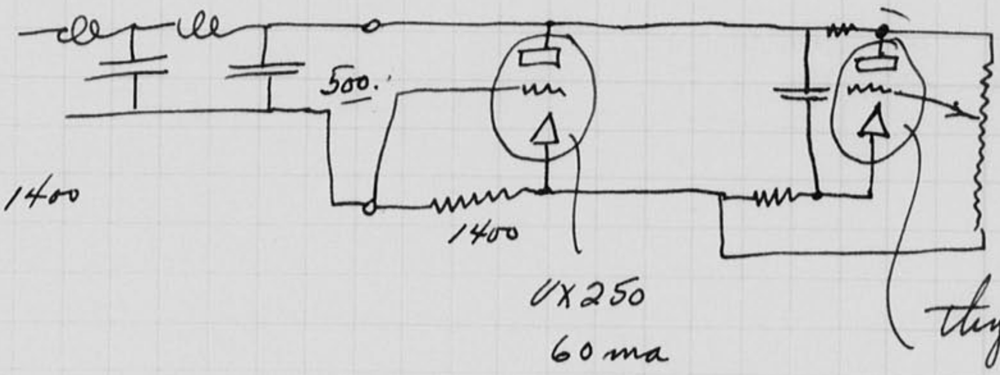
$v = (1 - b\cos 2\theta)$.

May 22/1931
J. E. Edgerton.

Cont of Strobo of page 93.

V.T. adjusted so that it will draw a current such that the current from the filter is constant.

$\frac{80}{.055\text{ ma.}} = 1400$



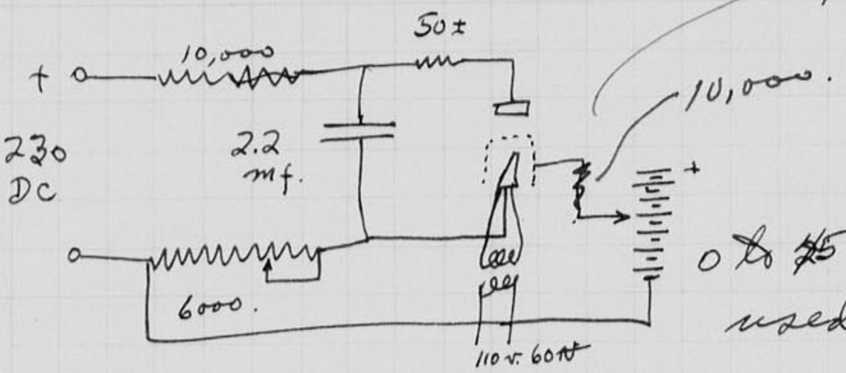
Design Resistances etc ~~the~~ so that ~~the total~~ current is a constant. The charging current increases the bias and reduces the current drawn by the 250. tube.

May 26, 1931.

Stroboscope

Circuit described on page 94 connected up and tried.

F.G 27.



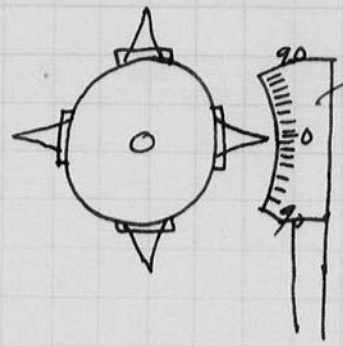
0 ~~to 45~~ volts bias used.

There is a periodic variation of the flashes which is apparently due to the interference of the voltage on the filament. The 60 cycles beat with the frequency of the flash circuit.

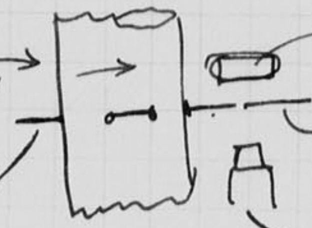
An F.G. 33 did not work on this circuit for some reason. It would flash when the grid was connected to the anode but would not operate with the grid + ~~22~~ 45 volts!

~~Stroboscopic Movies.~~

May 28, 1931
H E Edgerton



Scale with slots for the light to shine through.



light. 60 cyc sec flashes.

Shaft

scale

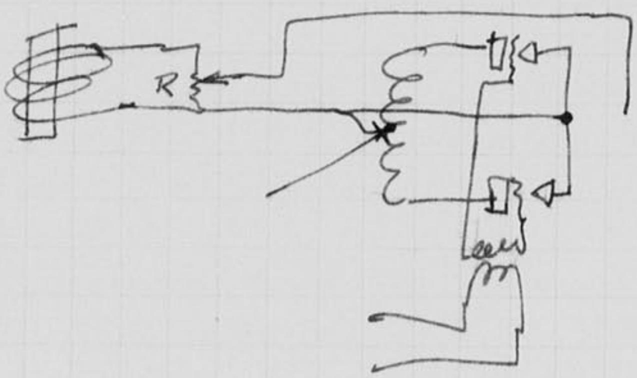
Pointers.

camera Example 16 mm film driven at const speed by a small synchronous motor so that there would be 60 frames per second. A relay system would start the camera and the stroboscope simultaneously.

May 29/1931. Field-Switching for Synchronous Motors

H Edgerton.

A thyratron supply on the field of a synchronous motor can be made to supply intermittant field current so that the field is on from 0 to 180 degrees and is off from 180 to 360 (generator angles).



X m.g.

May 30 1931
H. E. Edgerton.

Phase angle control of thyratrons.

Ref. W. B. Nottingham. March 1931 p 271.
"Characteristics of small grid-controlled hot-cathode mercury arcs or thyratrons

He shows a 24 degree (60 cycle) phase shift in curves for an F.G. 27 and a FG 17. The circuit that he uses depends upon a condenser ~~and~~ a resistance for the phase shifting. The angle is calculated since R and C are known. This shift in phase corresponds to 1×10^{-3} seconds or 1000 ~~micro~~ sec. which is a very long time.

I am sure that this question needs further investigation. It may be possible that the current in the grid circuit makes his calculation of phase angle invalid especially since the R and C must be in a steady state in order to compute the angle by the impedance method.

if $\alpha = 45°$ $R = 1 \times 10^6$ ohms.
$X_c = 1/\omega C = 1 \times 10^6$ ohms.

$C = \frac{1}{\omega X_c}$

time const of phase shifting circuit. $= T = RC = R\frac{1}{\omega X_c} = \frac{1 \times 10^{+6}}{377 \; 1 \times 10^6} = \frac{1}{377}$ sec.

$= .00265$

Another factor which may make his angle calculations invalid are currents between the anode and grid before conduction. I have noticed such a glow between anode and grid in the longarm glass thyratrons before the main arc strikes.

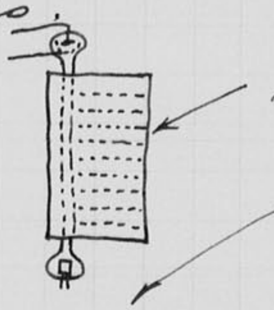
June. 16, 1931. ~~Photograph~~

H.E. Edgerton

Movie Projection by means of intermittant light.

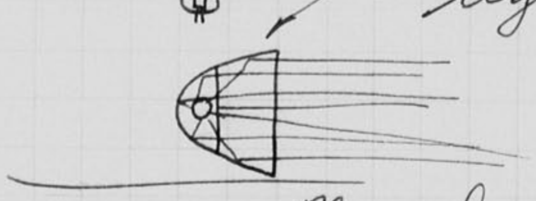
Practically all present projection schemes use a concentrated light source which approaches a point source.

Such a point source appears at the present to be impossible with the mercury arc lamp. It may be possible however to use a line source of light to advantage. I believe that an intense capilliarly can be built which will be small in diameter but very intense. A parabolic mirror and parallel light shields may make it feasible to get a parallel beam of light which may be directed and focused by means of cylindrical lenses.

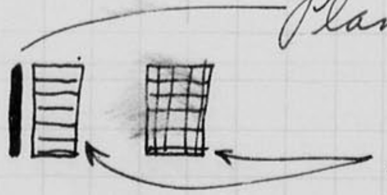


light baffles to make the light parallel.

Parabolic reflector to make light directive.

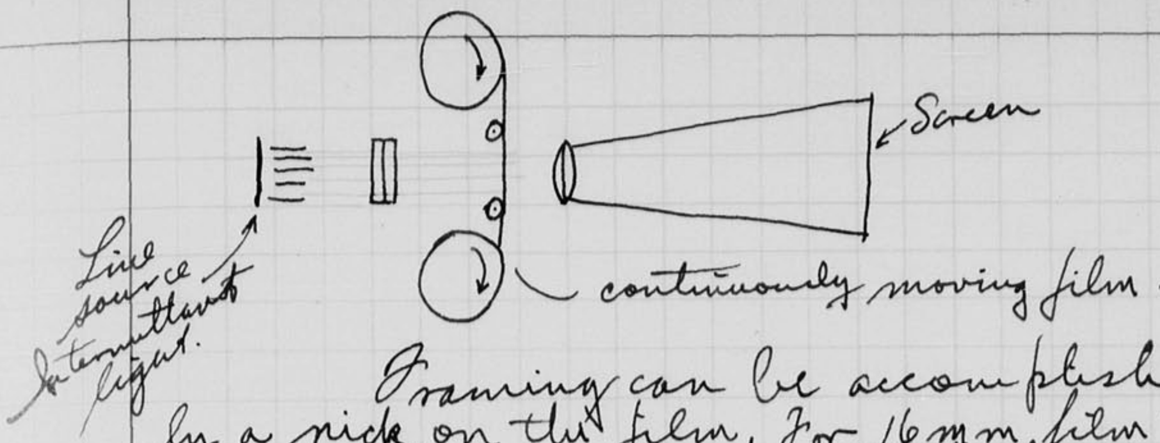


Plane light source.



light grid to make beams parallel.

During the last week I worked at the Sprague Specialties company at Quincy on the motor driving the Visivox. These intermittant light schemes were discussed at length with Bill Dunn. constant speed film seems to have advantages



Framing can be accomplished by a nick on the film. For 16 mm film the sprocket holes will accomplish this purpose.

Notebook # 3

Filming and Separation Record

____ unmounted photograph(s)

____ negative strip(s)

1 unmounted page(s)
(notes, drawings, letters, etc.)

was/were filmed where originally located between page ____ and ____.
in side back cover

Item(s) now housed in accompanying folder.

Nov 15

Oscillation data for determination of WR^2

I_f 804^A	$V\phi$	$E_a\phi$	X_s	time in secs	Cycles of oscill.	WR^2	
4.0	$120/\sqrt{3}$	68.5	3.26	34 23	15 10	323	
8.8	$126.5/\sqrt{3}$	140	"				
8.7	$124/\sqrt{3}$	139	"	32 ? 29.75	20		from 187
8.7	$123/\sqrt{3}$	139	"	30.0		294	KVA
5.92	$120/\sqrt{3}$	101	"	36.5	20	309	machine.
4.15	$118/\sqrt{3}$	63.5	"	16 ? 17.5	15		iron core
"	"	"	"	18.25	15	278	reactors

Iron core removed from reactors.

4.15	$115/\sqrt{3}$	73	1.41	19.5	15	252	from 187
"	"	73	1.41	20	15	266	KVA
8.3	$231/\sqrt{3}$	134	1.41	20.25	30	250	machine

machine operating from bus.

2.9	$226/\sqrt{3}$	50	1.09	13.5	15	210

H. E. E.