HAROLD E. EDGERTON

PAPERS

MC 25

SERIES 3. LABORATORY NOTEBOOKS

NUMBER: T-1

DATED: 26 September 1927 TO 16 July 1931

250

Sept. 26, 1927
July 16, 1931

NOTEBOOK T1

THYRATRONS. I.

Massachusetts Institute of Technology

COMPUTATION BOOK

NAME

H. E. EDGERTON

Course

Used from SEPT 26 1927, to JULY 16 ...31

United States Patent Office
Before the Examiner of Interferences

Trucksess:
vs. : Interference 73,473

Edgerton Exhibit 23
Notebook T 1

Mar. 1, 1937

Clara Schlosky
Notary Public

10-13-1927.
Edgerton

Speed Control.

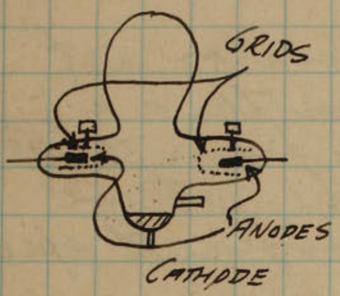
For various purposes in the laboratory it is desirable to have a source of constant frequency alternating current. This frequency must be exactly 60 cycles.

There is a motor generator set in the laboratory rated 5 kW on the a.c. generator. The motor is run from the 250 volt D.C. mains. This is the set we wish to have run at a constant speed.

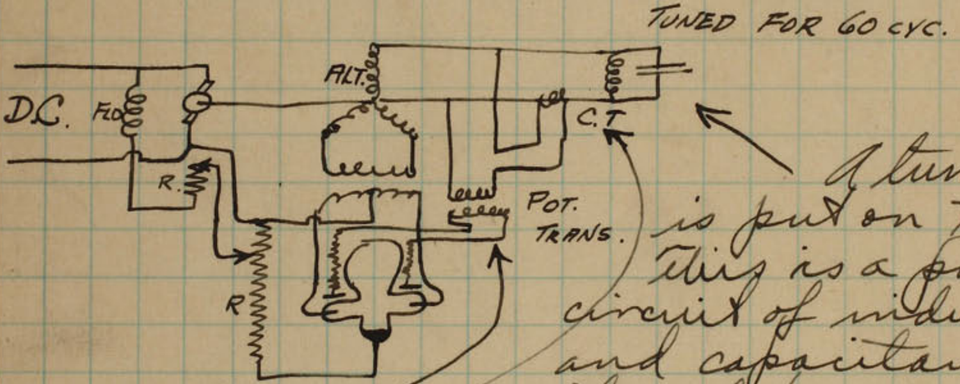
10-13-27.

Speed Control by the thyratron tube.

A mercury arc rectifier is made by the General Electric Co which has grids around the anodes. this rectifier is called the thyratron. the sketch shows the general layout of the tube.



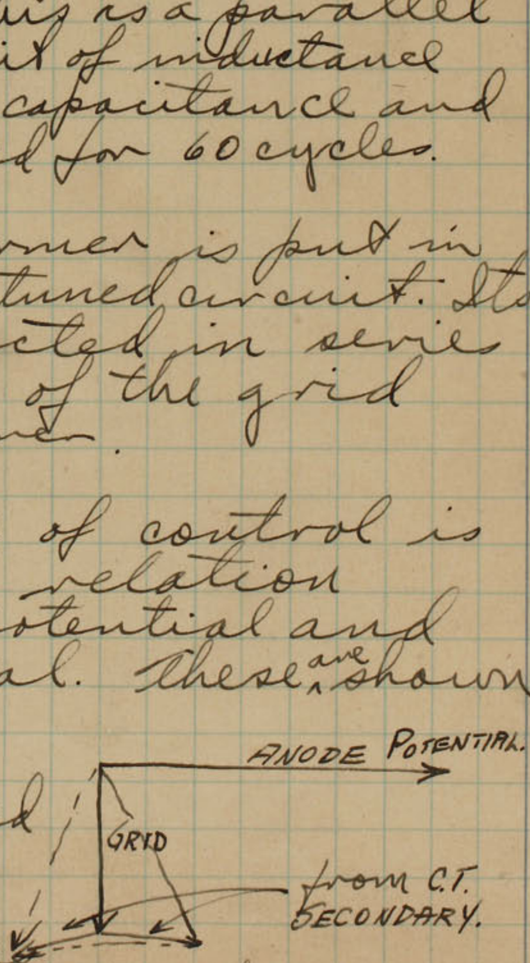
the circuit shown below was devised to control speed of the D.C. motor by varying its field current.



A tuned circuit is put on the alternator. this is a parallel circuit of inductance and capacitance and is tuned for 60 cycles.

A current transformer is put in the line going to the tuned circuit. Its secondary is connected in series with the primary of the grid potential transformer.

The whole scheme of control is to shift the phase relation between the grid potential and the anode potential. these are shown on a vector diagram ~~are shown~~. To the grid potential is added a potential which depends upon the frequency, this comes from the C.T. in the tuned circuit



Notebook Number: T-1

Scanning and Separation Record

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(notes, drawings, letters ...)

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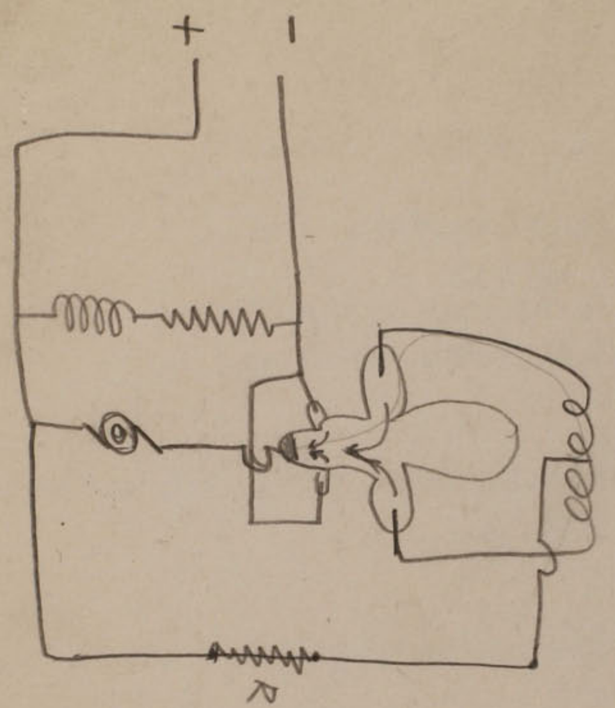

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12-130

Mass

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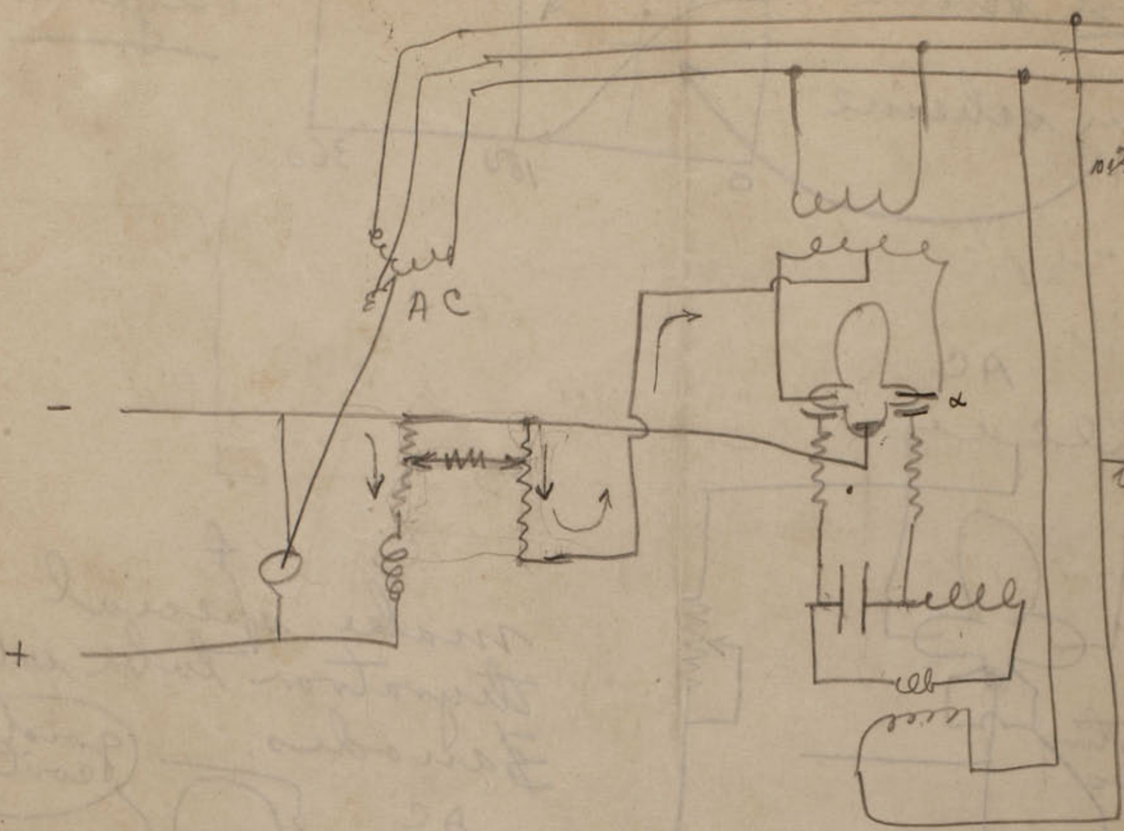
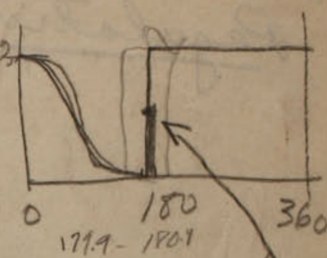
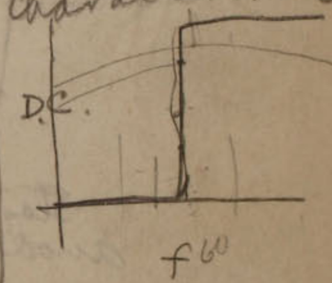
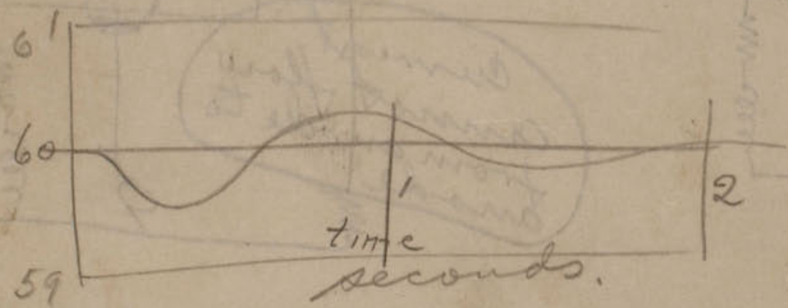


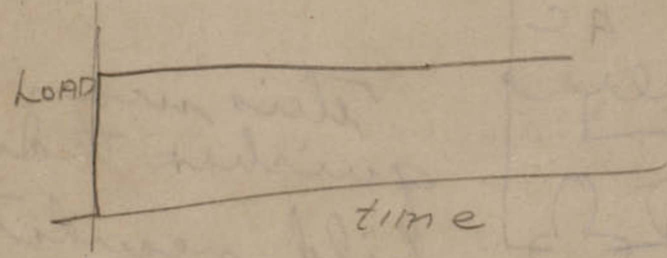


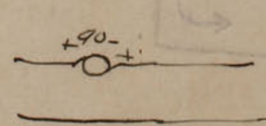
adjusted for this part of characteristic

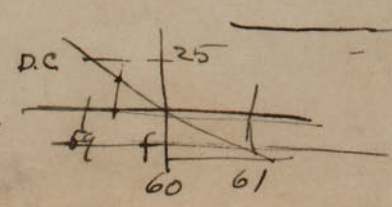


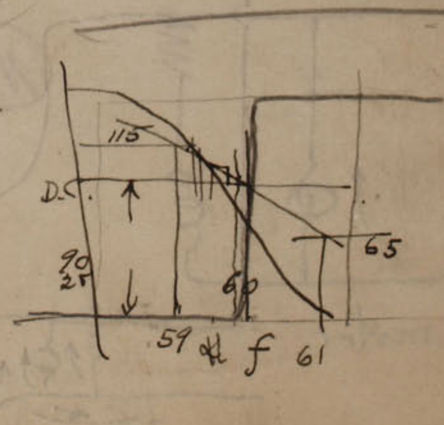


Holds
60.00 ± .05
for all
loads from
0 to 150%



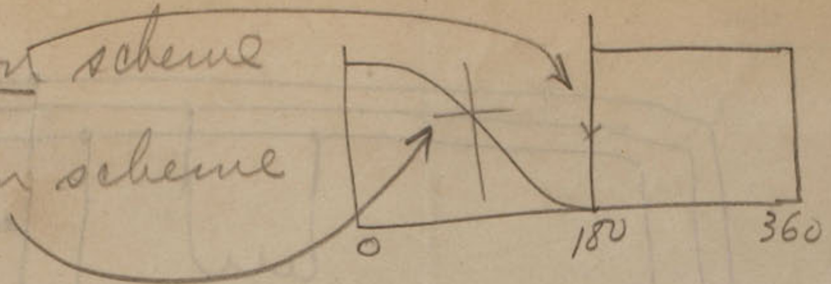


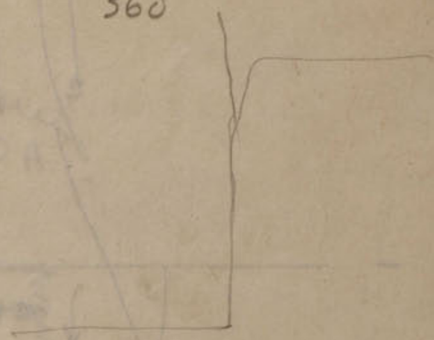


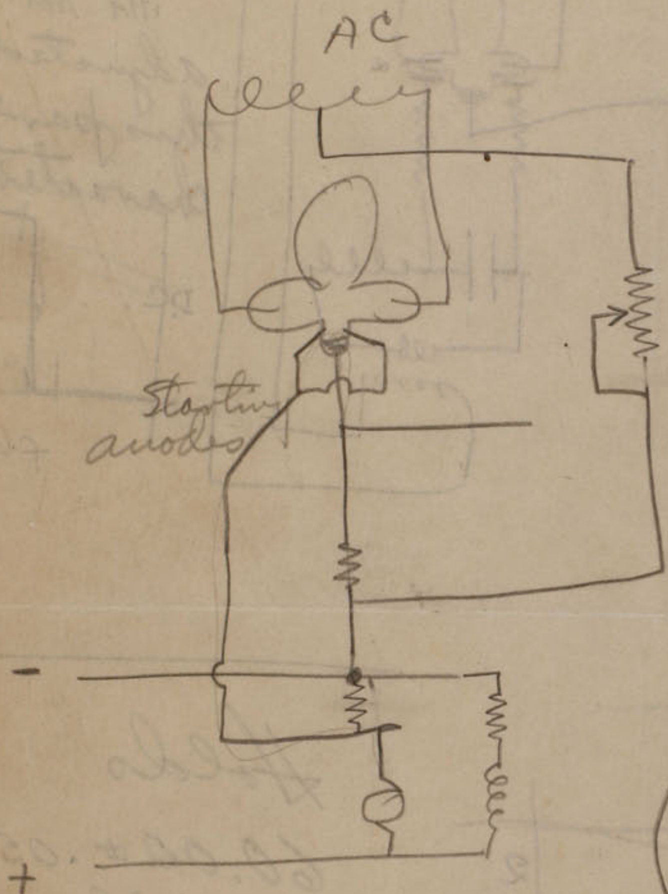


10-20-1927
Edgerton

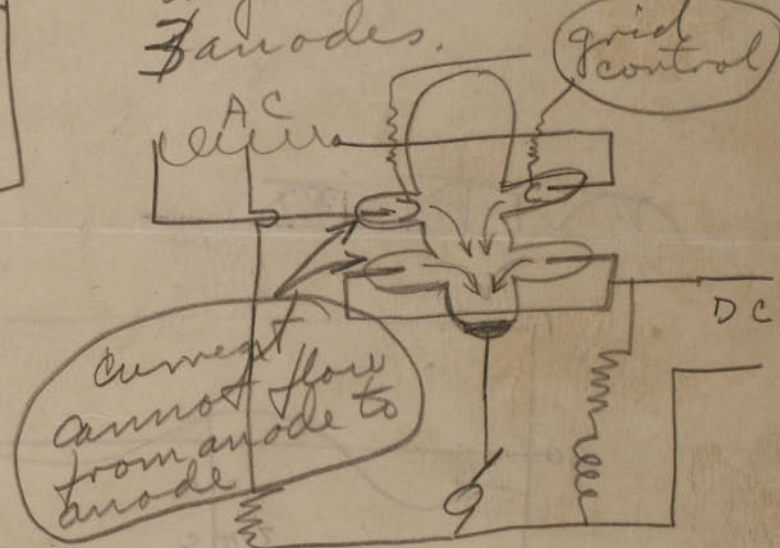
Off and on scheme
or
Regulation scheme

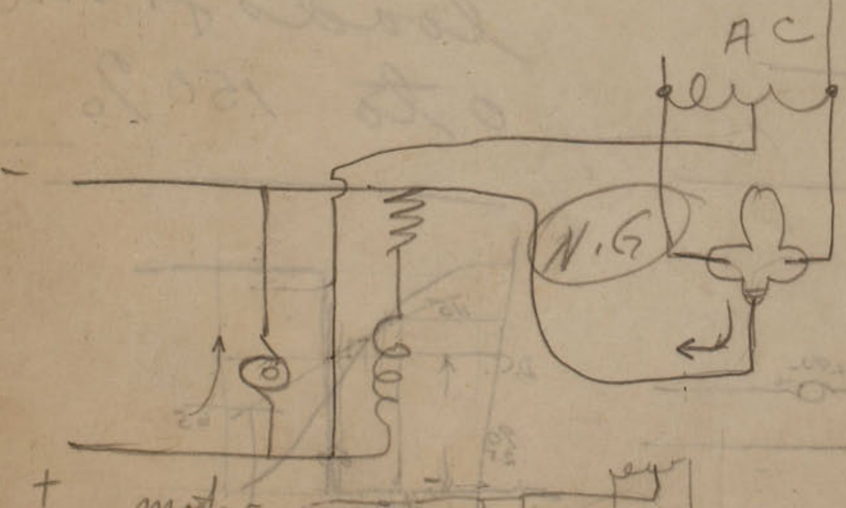






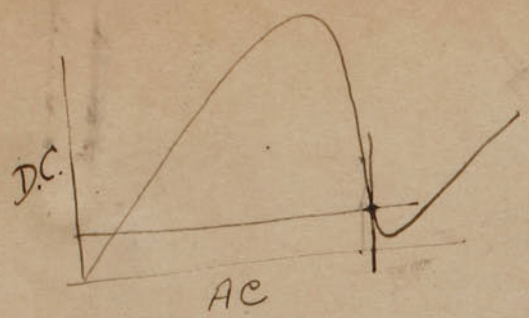
make special thyratron tube with 3 anodes.

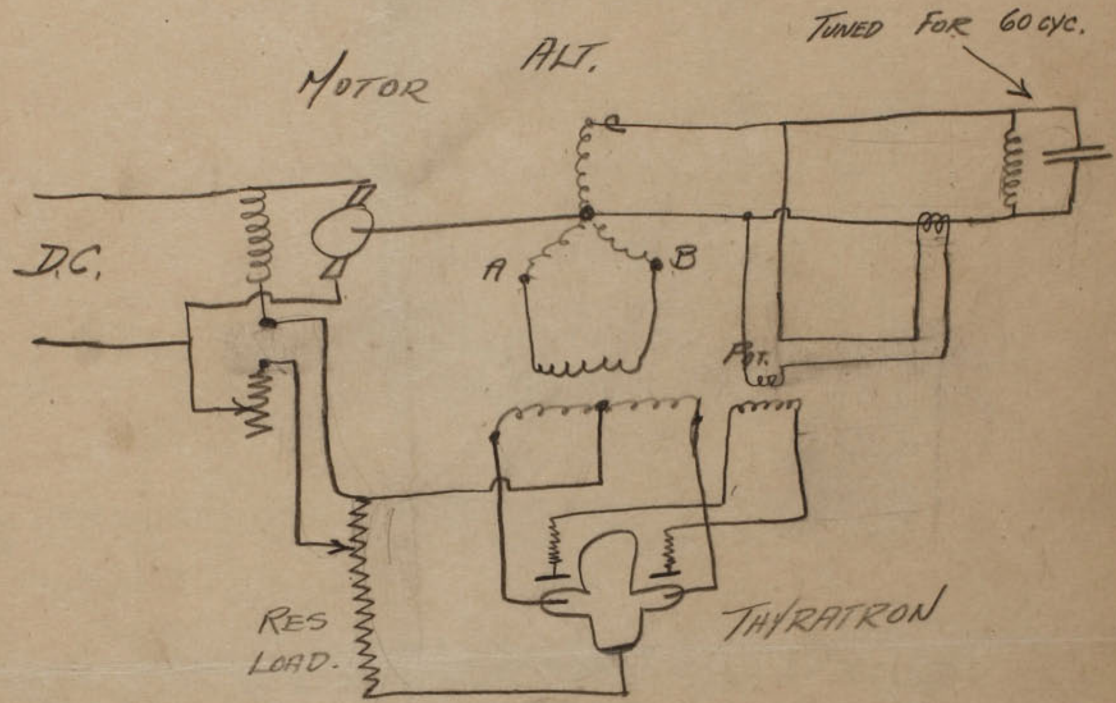


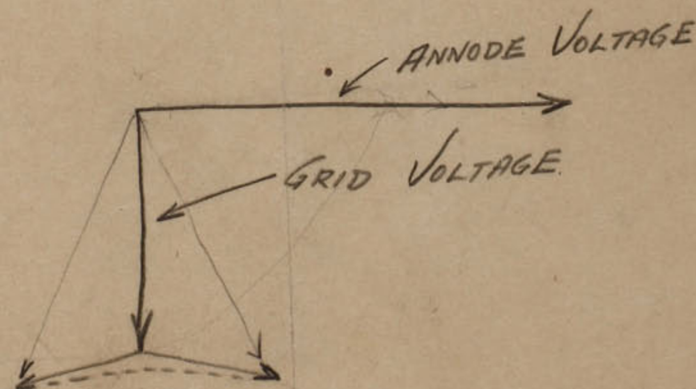


This may be quicker than the field regulation.

over for present hookup







VARIATION CAUSED
BY FREQ. CHANGE.

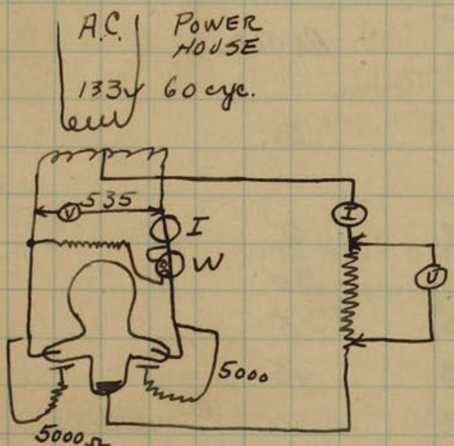
<u>METHOD OF SPEED CONTROL</u>

H.E. EDGERTON
SEPT. 15, 1927.

10-13-27
Edgerton.

The rectifier supplies current to a ~~rectifier~~ resistance load. From this any percentage may be tapped off to control the D.C. motor field as shown in the wiring diagram.

A 20 ampere thyratron tube has been purchased and will now be tested.



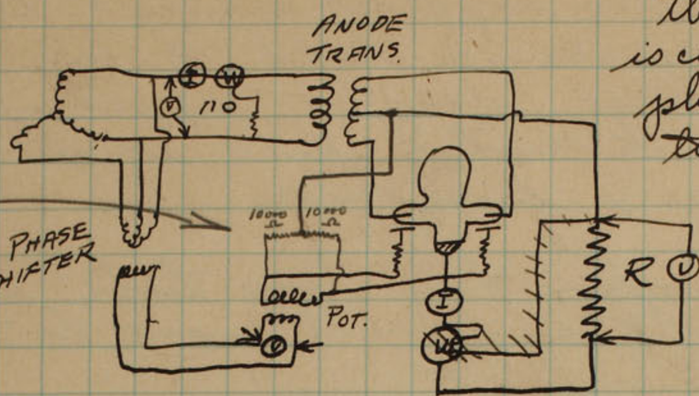
Load curve.

This was not carried farther due to the rating of the transformer supplying the anode voltage.

A.C.				D.C	
V	I	W	f.	E	I
K D	D	x20	D	D	D
528	1.23	22.	60	217	1.62
527	1.65	30	60	216	2.20
527	1.86	34	60	216.5	2.44
524	2.31	43	60	215.0	3.05
520	2.78	51	60	214.0	3.65
518	3.17	58.5	60	213.0	4.17
520	3.52	66.0	60	215.0	4.67
522	3.79	69.8	60	215.0	5.02
538	–	–	60	220	–

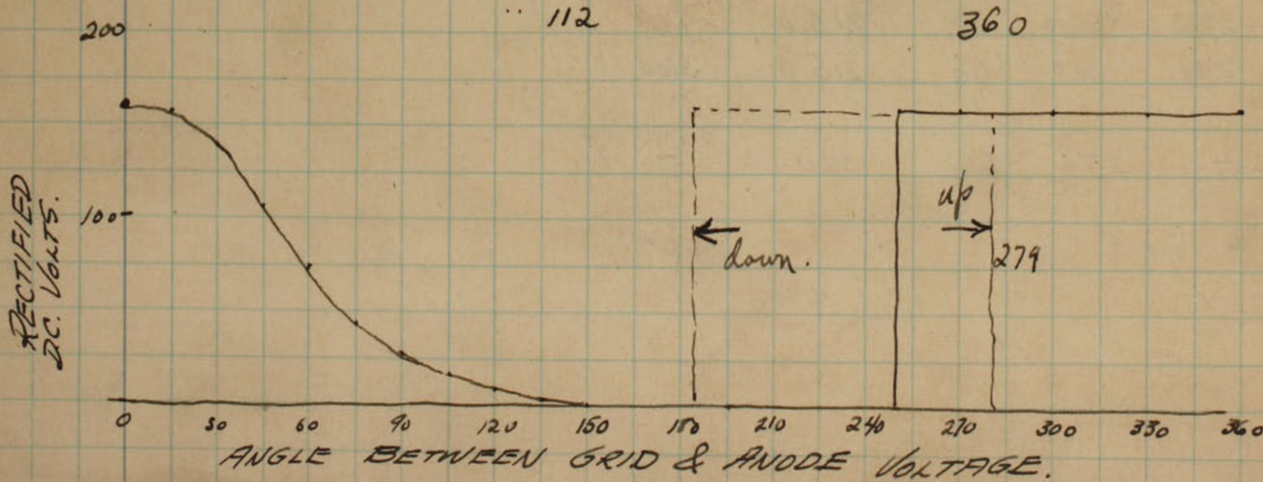
10-13-27
Edgerton

PENCIL CONNECTIONS USED FOR PAGE 7.



The grid circuit is connected to a phase shifter to investigate the effect of phase shift between the two.

A.C.					D.C		
V	I	W	f	V_G	V	I	ANGLE.
K D	D	20	D	Dx10?	D	D.	D.
420	3.34	49.4	60	110	169	4.39	0
420	3.07	42.5	60	113	136	3.57	30
420	3.26	47.5	60	112	160	4.15	15
422	2.72	33.5	60	115	108	2.83	45
424	2.22	22.0	60	113	74	1.90	60
430	1.72	12.0	60	117	41	1.06	75
433	1.38	8.5	60	118	29	.73	90
438	1.05	5.5	60	118	17.0	.48	105
442	–	2.5	60	117	10.0	.26	120
444	–	–	60	118	3.0±	.10	135
443	–	–	60	118	–	–	150
				..			180
				..			210
				..			240
418	3.32	49.5	60	115	169	4.38	248
				.. 116			300
				.. 115			330
				.. 112			360



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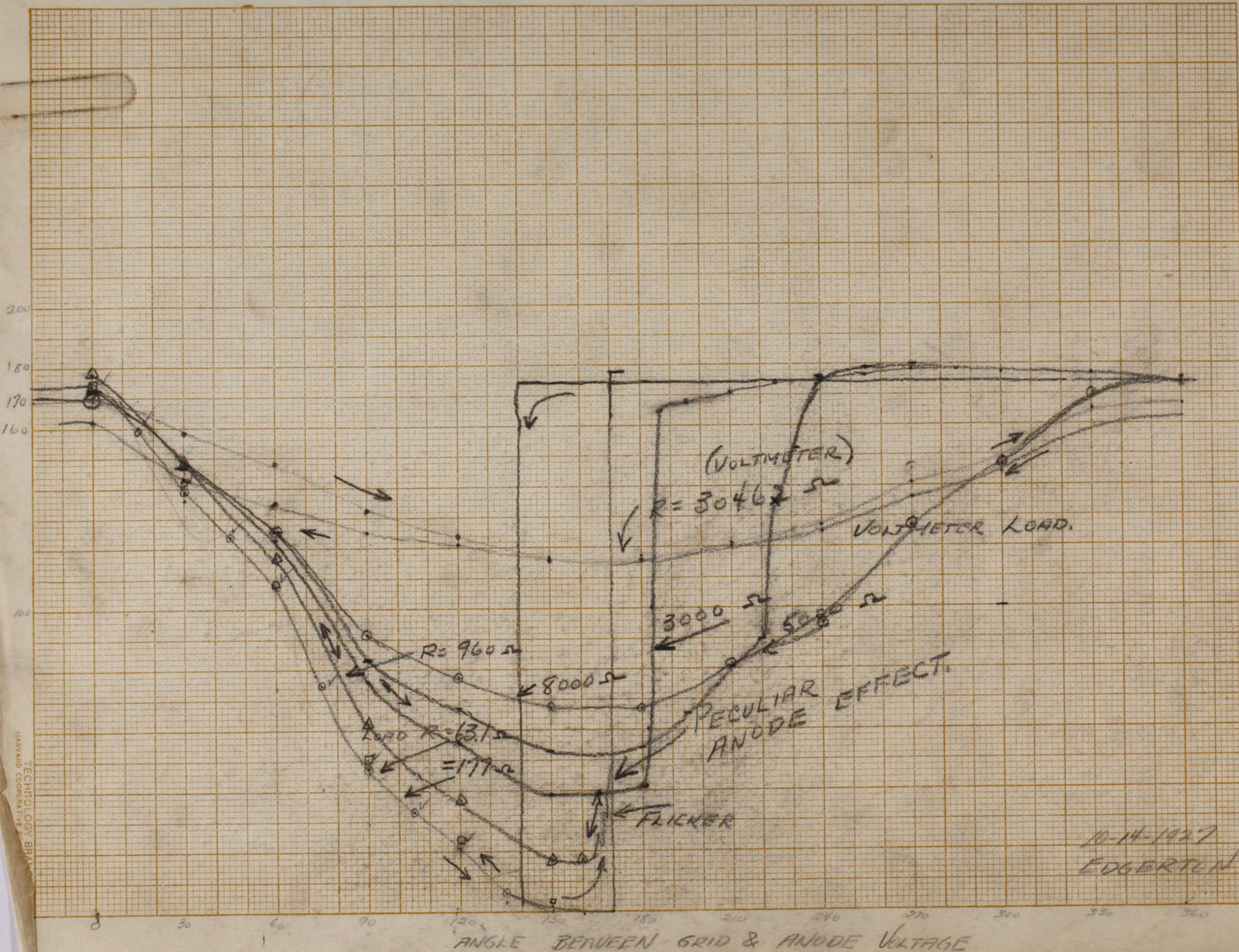
121
125

120
90

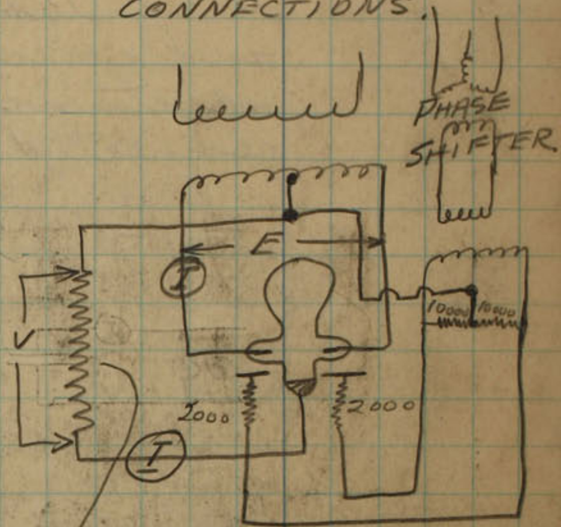

200
180
170
160
100
(VOLTMETER)
R = 3046 Ω
VOLTMETER LOAD.
3000 Ω
5080 Ω
R = 960 Ω
8000 Ω
PECULIAR ANODE EFFECT.
LOAD R = 131 Ω
= 177 Ω
FLICKER
10-14-1927
EDGERTON
0
30
60
90
120
150
180
210
240
270
300
330
360
ANGLE BETWEEN GRID & ANODE VOLTAGE
TECHNOLOGY BRANCH
HARVARD COOPERATIVE SOCIETY

These tests are the same as the ones on the other page except that the center points of the anode and grid transformers are connected.

10-14-29

	V	I	W	f	VG	V (D.C.)	I (D.C.)	ANGLE
	D	D	×20	D	×10?	D	D.	D.
	434	208	-	60	37.	174	2.74	360
	434	2.04				159	2.52	15
	434	1.92				138.5	2.19	30
	434	1.81				124.0	1.97	45
	434					107.		60
	434					74.5		75
	443					47.5		90
	443					33		105
	445					21		120
	448					6		135
Increasing angle	449					2		150
	434					174		170
Decr angle	449				37	DROP. 0		140
	447					21.5		120
	446					34.5		105
	443					48.5		90
	338					75.0		75
	337					107.5		60
	335					125.5		45
	334					139.0		30
	334					159		15
	334					173		0
	335					175		345
	336					175.5		330
	449	0		60	37	170	0	360
	449					158		30
	449					148		60
						132		90
						124		120
						116		150
						116		180
angle up						121		210
						127		240
						141		270
						149		300
						165		330
						167		360
angle down						144		300
						136		270
						125		240
						120		210
						117		180
						117		150
						121		120
						125		90

GRID & ANODE CONNECTIONS.



63.1 ohms

2.74) 174.00.
1644
860
822
380

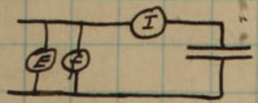
ANG	E
60	135
30	143
0	162
330	162

More points taken with other loads are plotted directly on the curve sheet.

A 60 cycle tuned circuit (parallel)

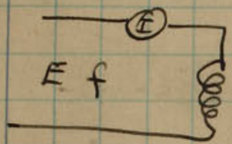
Three condensers 8.8 mf 9.78 m.f. 8.49 m.f. and an air core reactance with a variable reactance (mutual) i.e. variable coupling, connected in paralel.

Test of circuit containing condensers



E	f	I
111	60	1.13

Inductance circuit



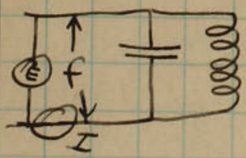
111	60	1.33.

1.33 − 1.13 = .20 amperes of leading current needed. This requires a condenser of a capacity.

$$C = \frac{I}{2\pi f E} = \frac{.20}{111 \; 377} = 4.78 \text{ m.f.}$$

A total of 31.75 mf is needed for resonance to occur at 60 cycles. Three condensers were obtained (1.95 + 2.28 + .50) mf. bringing the total to 31.8 mf. The .5 mf condenser burnt out so only 31.3 mf remains.

The parallel circuit was now connected up and found to be O.K.



E	f	I
110	55.7	.235
110	57.25	.190
110	56.1	.198 MA143
110	57.35	.158
110	59.3	.128
110	61.3	.136
110	62.2	.154
110	60.4	.127
110	59.8	.126

10-14-27
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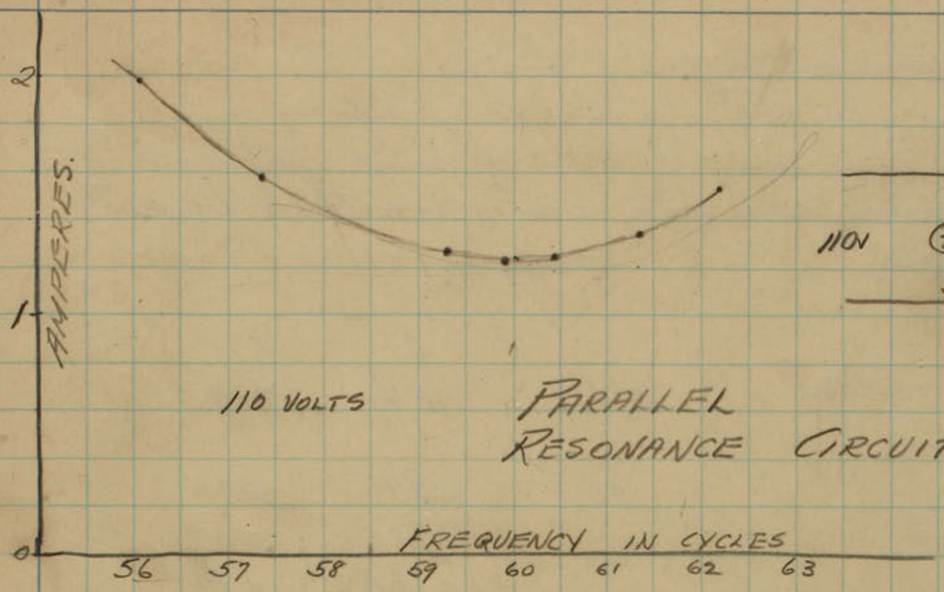
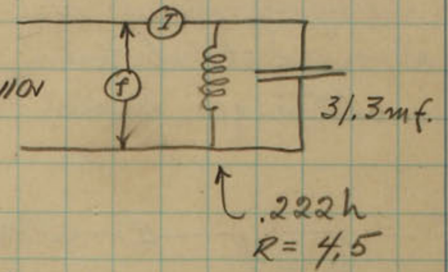
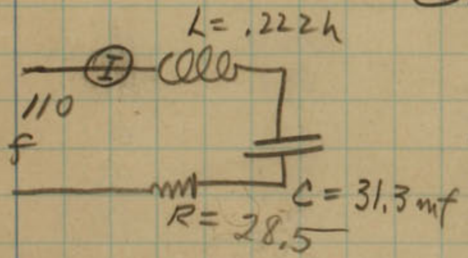




This curve shows that the parallel resonance circuit will not give critical enough control to hold the frequency within limits desired.

By using a great deal more condensers in parallel and a smaller reactance with a smaller resistance this curve could be made much sharper in the V portion. This was not considered feasible because of the bulk needed by the condensers.

SERIES RESONANCE



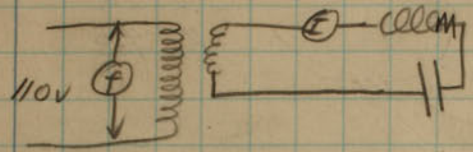
E	f	I
MV14	Mf4	MA9
110	61.1	3.42
110	59.3	3.48
110	57.5	3.47
110	56.3	3.42

Worse than the Parallel!

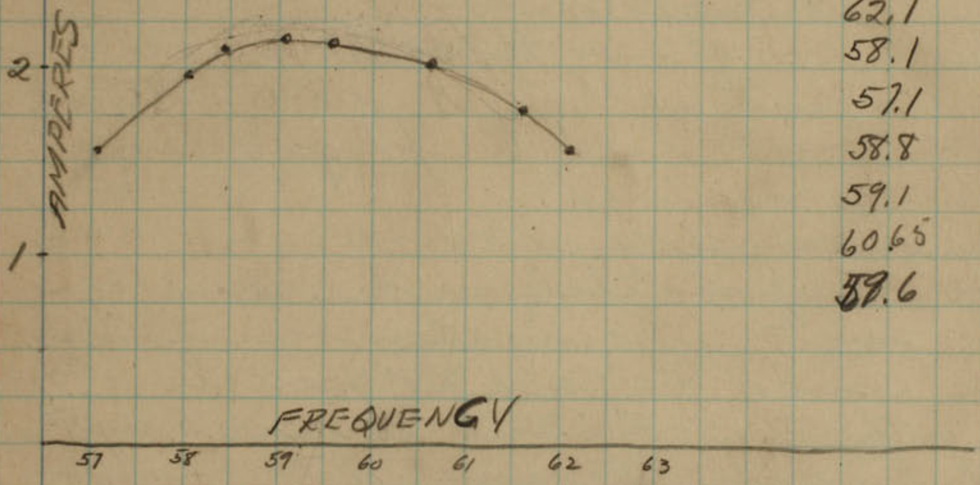
This can be made sharper by reducing the resistance but doing this allows the current to become excessive. A Potential transformer will cut this down by reducing the voltage impressed.

10-14-27

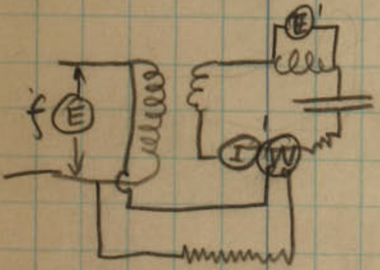
A filament lighting transformer was connected across the variable frequency supply and the inductance and capacity connected in series across the low voltage side:



E MV14	f MF4	I MA9.	
110	58.45	2.15	
110	59.85	2.21	?
	61.60	1.77	
	62.1	1.60	
	58.1	1.95	
	57.1	1.64	
	58.8	2.1	
	59.1	2.17	
	60.65	2.0	
	59.6	2.15	



E	f	W ×5	I'	E' MV12	cos θ	θ
110	62.8	29	1.63	126	.809	36
110	60.8	47.3	2.12	148	1.00	0
110	59.05	38.5	1.90	132	.921	23
110	57.5	23.8	1.47	103	.737	43
	57			94	0	
	57.7			104		
	59.3			135		
	60.8			148		
	63			125		

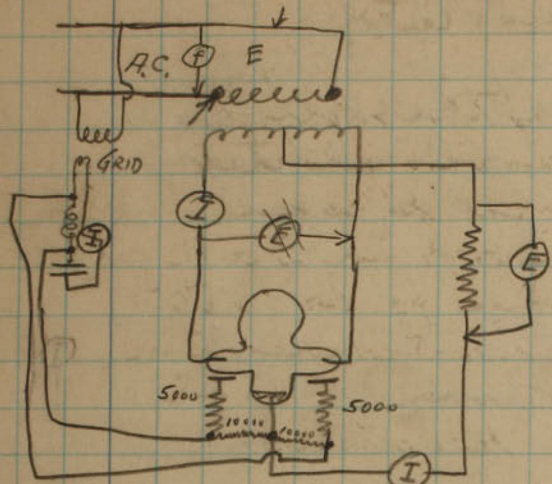


This looks better!! The magnitude swings some but the important thing is that the angle varies over a wide range, and it is the determining factor

10-14-27

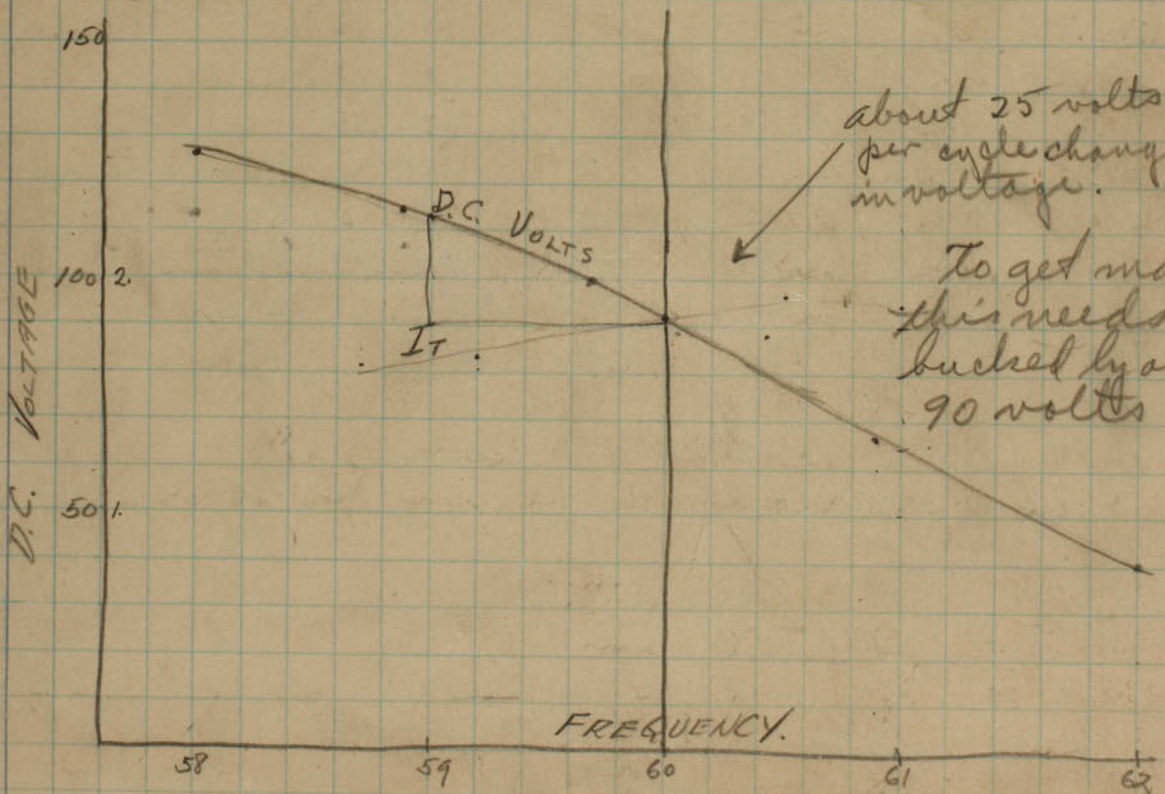
The idea now is to take the drop off the inductance, put it through the grid transformer. This drop gives a voltage which swings with frequency.

10-17-27
Edgerton



The drop across the inductance was found to be large enough to control the tube.

	A.C.			D.C.	
E	I	f	I_T	E	I
106	.5±	58	1.41	127	.72
109		58.8	(60 1.82)	115	
		59.7	(59.2 1.67)	100	
		60.45	(58.7 1.62)	78	
		60.9	(60.5 1.91)	66	
114+		62.0	(61. 1.89)	40	



about 25 volts per cycle change in voltage.

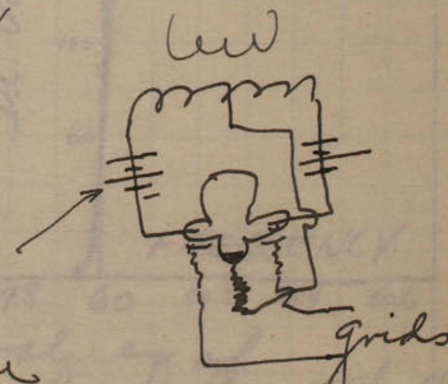
To get max. effect this needs to be bucked by about 90 volts D.C.

-18-27
gerton

Camb. Mass.
May 29 1929

When using the verticle cutoff point of a thyratron tube by having the grid voltage about 180 ± degrees from the anode, trouble is experienced due to inductance in the circuit. the angle which alows the anode to conduct is ~~less~~ different than the angle which stops the conduction.

this may be remedied by putting in a biasing battery in the anode circuits as shown in the figure.

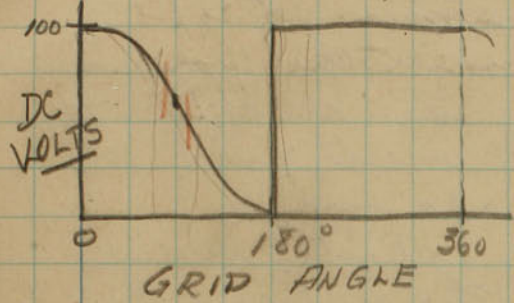


the object of these batteries is to have the instantaneous anode voltage negative until the other anode is through with its conduction. The size of the batteries will be determined by the a.c. anode voltage and the inductance.

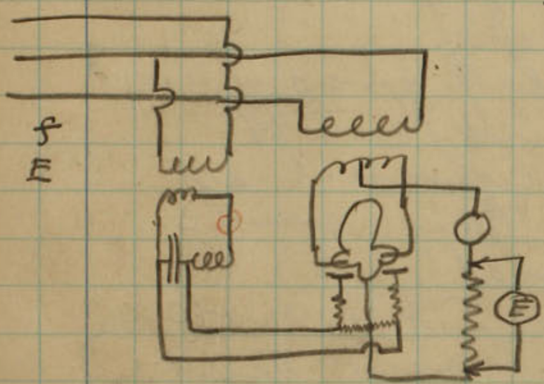
above.

10-18-27
Edgerton

Scheme using Vertical Cutoff.

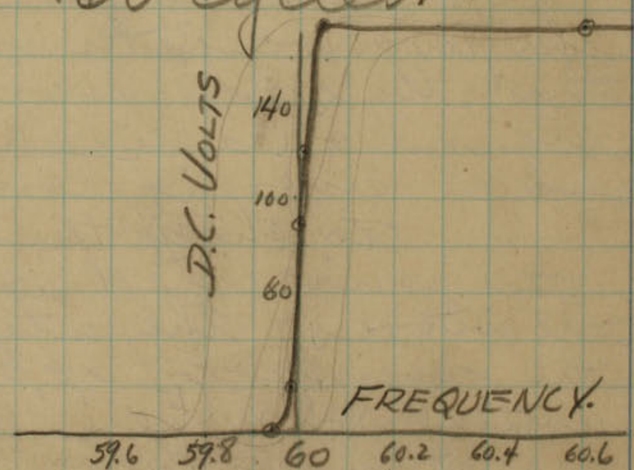


Observing the voltage rectified curves plotted against grid phase angle, we notice an abrupt cutoff at 180° when the load resistance has an ohmic value less than 100 ohms.

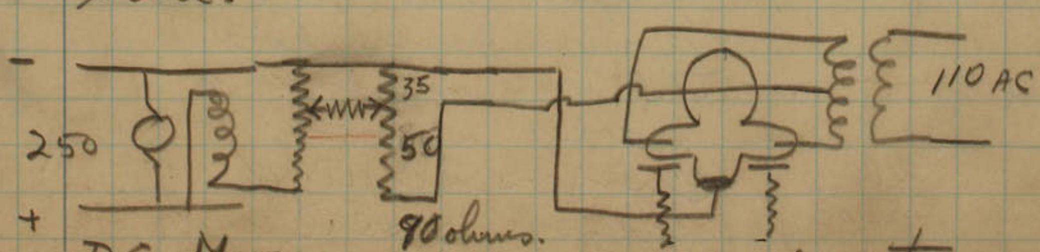


Connecting the apparatus up as indicated in the following wiring diagram gives us the below readings. L in the tuned circuit was varied so that cutoff would occur at 60 cycles.

E	f.	$E_{D.C.}$	I_{DC}
443	59.0	0	0
451	59.95	0	0
	59.99	20±10	
	60.0+	90±	
	60.02	120±	
438	60.10	176	2.86
440	60.6	177	2.88



It checks also on decreasing values of frequency. With 176/1.2 ohms load the cutoff and cutoff voltage differ by .4 cycles and the slope appears to be vertical on both.



WORKS O.K.

GRID circuit same as above.

10-19-1929
Edgerton

I connected up the outfit the same as yesterday except I used a lower tap on the anode transformer (3850) this was done in order to cut down the power required from the a.c. supply since apparently the cutoff occured at 1 amp. rectified D.C. Also slide wire resistances were substituted for the heavy stove resistances used yesterday. The values of current and the % voltages were about the same as before.

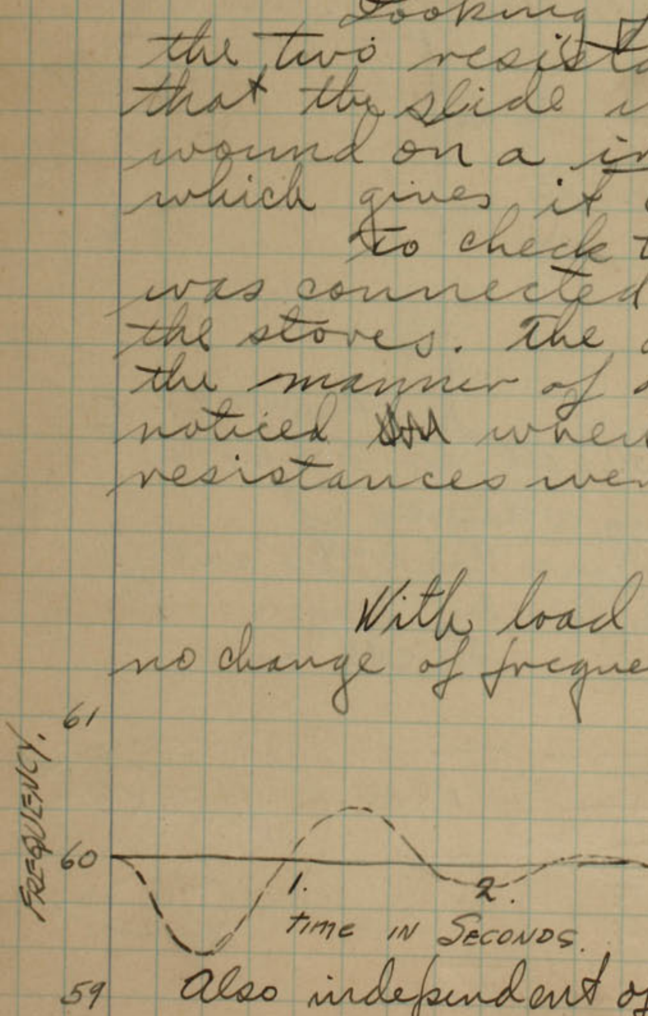
When I tried to regulate frequency I found that the cuton and cutoff occurred about at a difference in frequency of .5 cycle. This made speed regulation terrible!!

Connecting in the stoves which were used in the previous test the regulation was again O.K.

Looking for differences between the two resistances it is observed that the slide wire resistance is wound on a <u>iron tube</u> (enameled) which gives it considerabe inductance.

To check this guess, inductance was connected in series with the stoves. The cutoff varied with the manner of approching as was noticed ~~[illegible]~~ when the slide wire resistances were used.

With load on the A.C. generator no change of frequency was evident.



Sudden switching of 1½ times full load on the A.C. Generator gives a frequency curve similiar to the one sketched.

59 Also independent of d.c. or a.c. voltages.

Not enough of the field can be used.

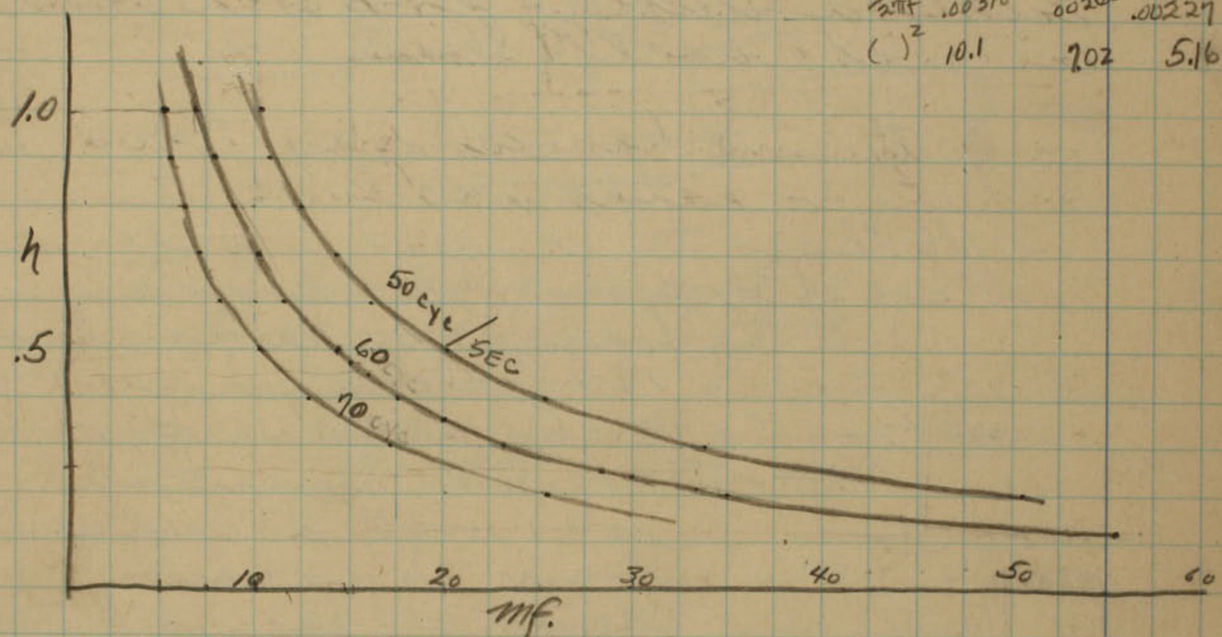
Ratio of L and C for a resonant circuit

$f = \frac{1}{2\pi\sqrt{LC}}$ $f = 60$

$\sqrt{LC} = \frac{1}{377} = .00265$

$LC = .00000702 = 7.02 \times 10^{-6}$

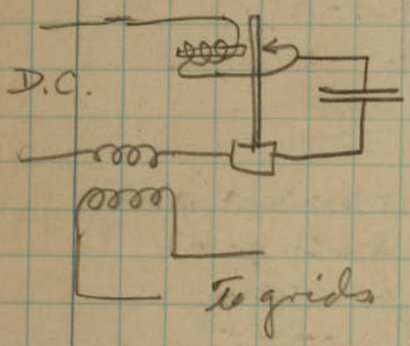
	50	60	70	
$2\pi f$	314	377	440	
$\frac{1}{2\pi f}$	.00318	.00265	.00227	
$(\ )^2$	10.1	7.02	5.16	$\times 10^{-6}$



10-26-27
Edgerton

The next scheme to be investigated is the "Synchronous D.C. Motor". Current is adjusted in the field circuit to hold speed constant. This system needs a referance frequency to stay in synchronism with. Either a tuning fork or a oscillating circuit will do.

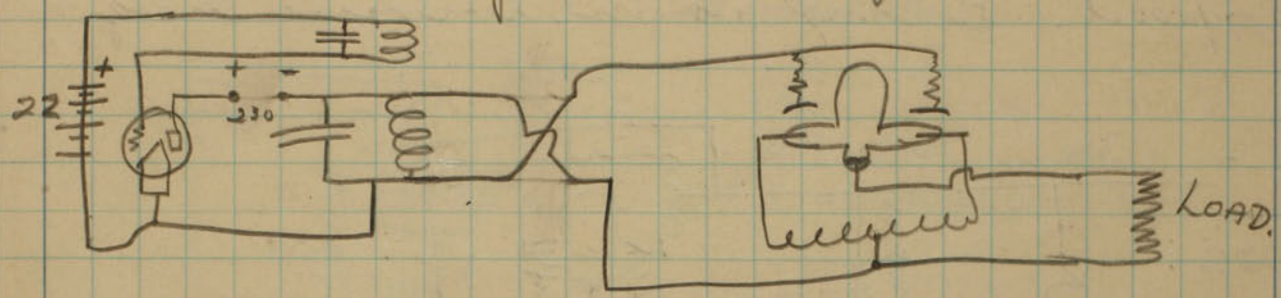
The mechanical was tried first. A buzzer outfit was built. A transformer in the lines to it gave a secondary voltage of a certain frequency. The frequency was about 120 cycles and was put on the grids in parallel.



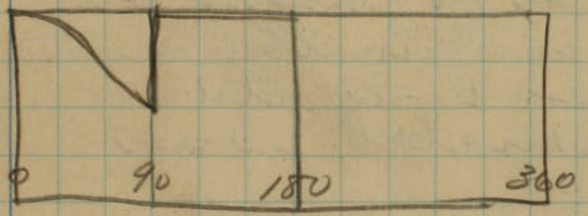
The output was not steady. Beats from various sources caused troubles. This type of oscillator was not investigated very thourally.

Edgerton
11-15-27

A vacuum tube oscillator was connected up to oscillate at 120 cycles. Its output was connected across the grids in parallel.



This arrangement gave a variation of thyratron output with phase angle between the independently oscillating tube circuit and the alternator.



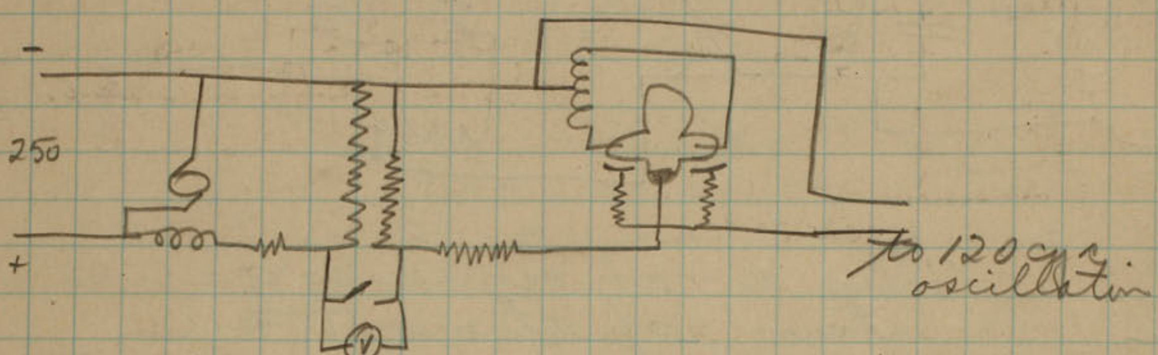
The variation is as sketched in the curve.

Notice that at 90° the full on occurs. This is becaus the 120° grid potential is positive because of the second wave coming in.

In order to connect back into the field circuit it was necessary to change the d-c lighting system to a.c. in order to avoid a short circuit.

1-16-27
Edgerton

The rectifier was connected so that it would feed back into the field circuit a correct amount of current to maintain constant speed. Below is the wiring diagram



The frequency of the m-g. set was made to be 60 cycles. Then the tuned circuit was adjusted until the variations in the voltmeter were small. When V = 0 the synchronising switch was closed.

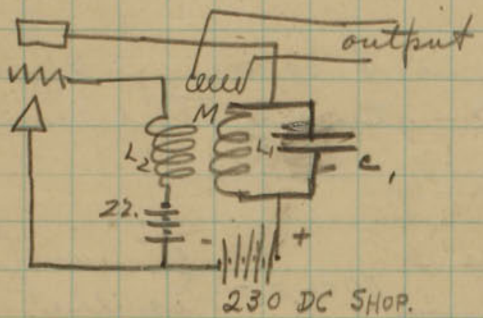
If the m-g set speeds up the anode voltage leads (more) the grid voltage. The current from the thyratron decreases and the current in the field increases. This tends to reduce the speed.

The opposite effects are evident when the speed of the m-g set is reduced.

The outfit worked O.K. but came out of step too easily. The field must increase faster!

11-23 1927
Edgerton

Some difficulty was encountered in getting a 60 cycle tuned circuit to oscillate with a vacuum tube. The below gives the present hookup which works satisfactory at 60 cycles

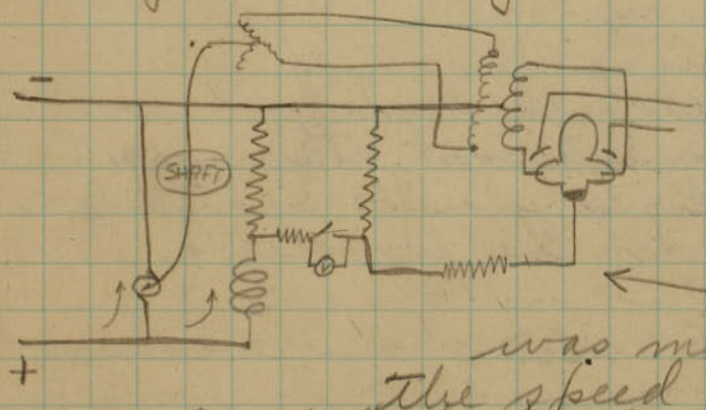


$\frac{n_2}{n_1} = \frac{3}{1}$

C_1 = about mf.

L_2 = ? L_1 = ? Iron core trans.

The output was put on the grids of the thyratron tube. Then the m-g set was run so that the frequency was 60 cycles. Beats in the rectified ac. voltage gave an indication of the exact frequency of the tuned circuit. By adjusting the inductance and capacity of the osc. circuit it was possible to bring the two systems into phase.



This connection was made and tried.

The speed did not hold constant but fluctuated a great deal. even when under no load conditions. Evidently the field current does not change fast enough.

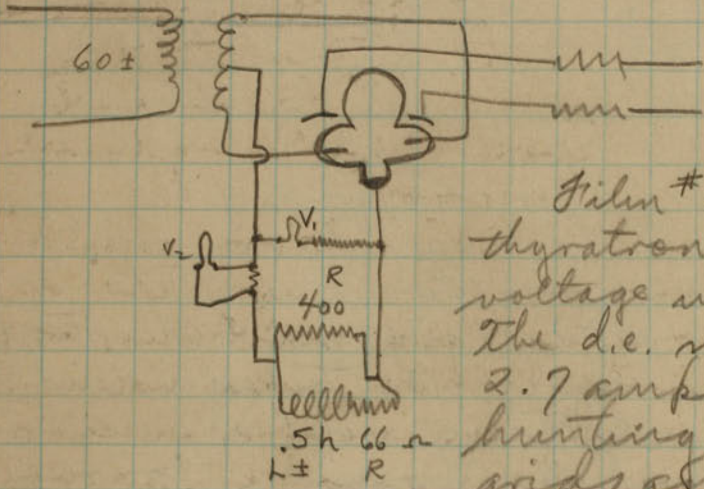
Looking from the thyratron side, the circuit is a parallel one consisting of resistance and inductance. We wish the current to go through the inductance i.e. field circuit. To accomplish this an inductance will be put in the resistance circuit.

11-25-1927
Edgerton.

Loads of different power factors (lagging) were tried on the thyratron circuit to determine the proper amount of inductance to use to smooth out the current wave.

12-9-1927

A single element oscillograph was connected up to study the circuits

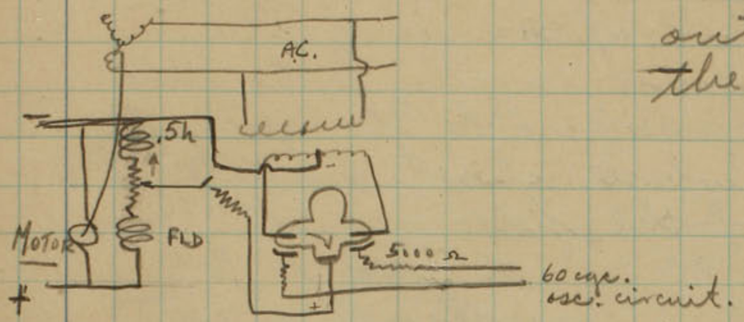


Film #1. Voltage across thyratron load circuit. The voltage was about 150. The d.c. meter read about 2.7 amperes and was hunting because the grids and the anodes were not at the same frequency.

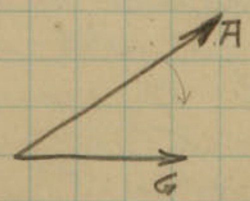
The two halfes of the rectified voltage were not of the same height. This was because the a.c. transformers neutral did not exactly split the winding.

The transformer connection was changed so that each half wave would be similiar.

Edgerton
12-13-1927.



The vacuum tube oscillating circuit was connected up and its output connected across the grids of the thyratron.



Many attemps were made to synchronize and hold the d-c. motor in step with the vacuum tube tuned circuit but none were successful.

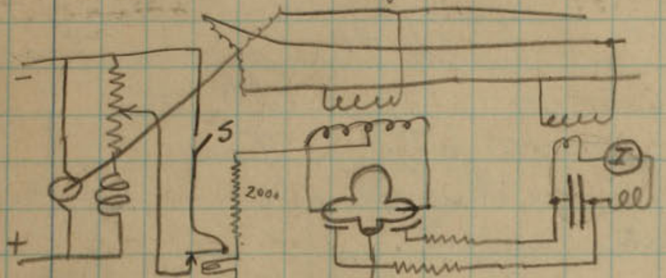
The speed would hover around synchronous for a few seconds and then would start accumulative hunting and fall out of step. i.e. the rectifier would give full rectifigation and the motor would speed up.

Either the effect upon the field circuit is not fast enough or the tuned circuit is desturbed by the conduction from the grid.

Edgerton
Dec 14.

Today I returned to the scheme using the verticle cutoff portion of the characteristic as described on page 13.

Instead of coupling the rectified current directly to the field circuit, it was made to operate a relay which short circuited a portion of the field reostat.



A large resistance was put in series with the contactor magnet in order to make the circuit time constant as small as possible.

When this system was tried out it was noticed that the frequency had a variation of about .5 of a cycle. I opened the switch S and regulated the frequency by hand. When increasing the frequency the contactor did not close until the frequency was about .5 of a cycle above that when it opened! I also noticed that the ammeter (I) changed its reading considerably when the main anodes of the thyratron were conducting. This shows that current flows in the grid circuit when current is flowing in the anode.

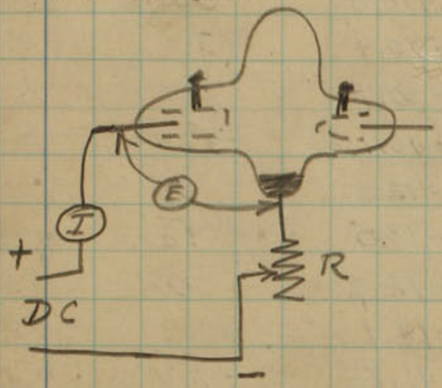
A. 15 m.a d-c. ammeter was put in one of the grid leads. Its reading was erratic, sometimes one way and sometimes another.

The next step was to put more resistance in the grid leads. The resistance was increased from 5000 ohms to 65,000. This caused less interferance with the tuned circuit but control was not positive at all times.

DEC 27-1927
EDGERTON

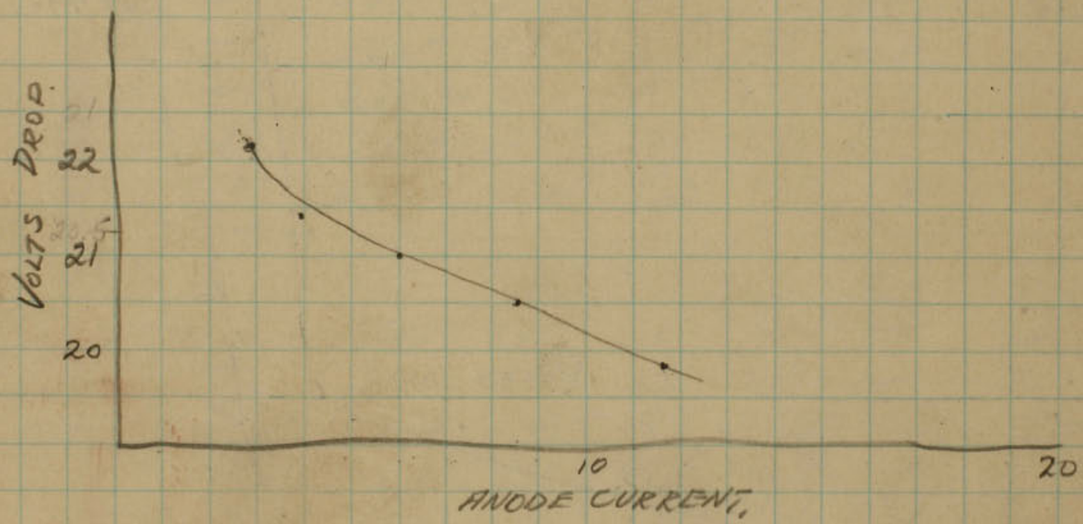
CHARACTERISTIC CURVES OF VT-42.

ARC DROP.

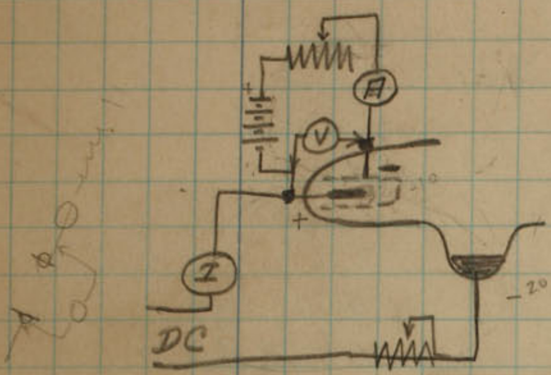


I	E	
MA 128	MV 73	GRID OPEN AFTER START.
6.0	21.	
8.3	20.5	
9.4	20.0	
11.6	19.8	(anode red hot).
4.0	21.4	
2.9	22.2	

goes out about 2.5 amps.



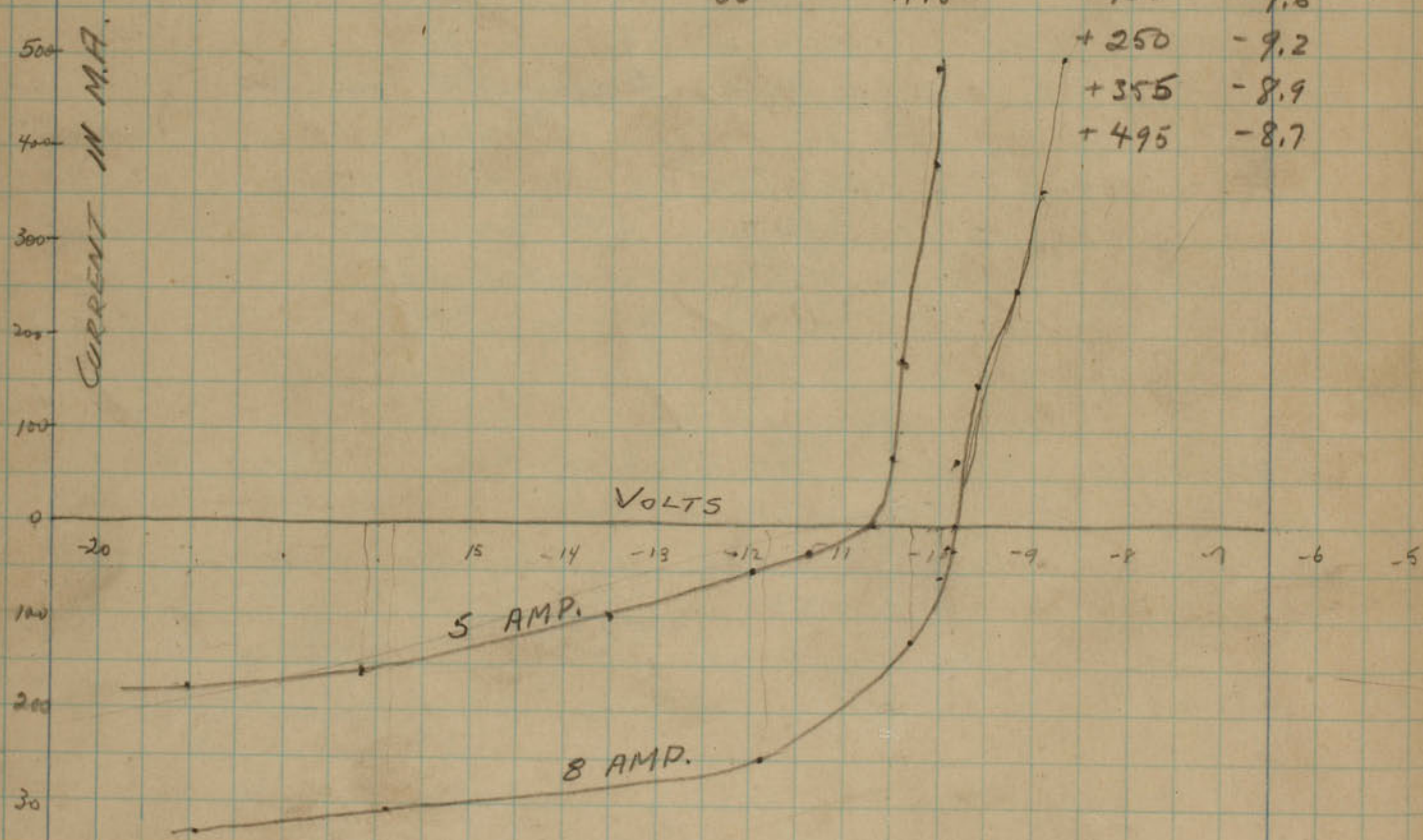
GRID-ANODE VOLT-AMPERE



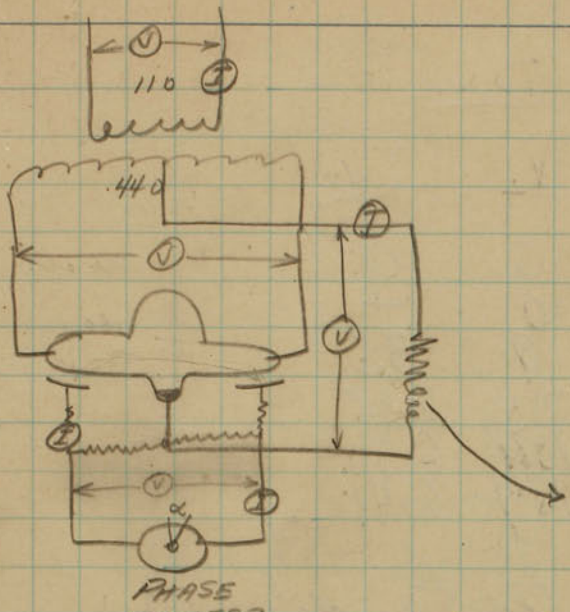
I_{ANODE} MA128	I_{GRID} MA 137	V MV 13
5	0	-10.7
"	+ 75 MA	-10.5
"	+ 180	-10.4
"	+ 355	-10.1
"	+ 480	-10.1
↓	- 50	-12.0
	- 100	-13.5
	- 168	-16.2
	- 182	-19.1
	- 30	11.8

8 AMP ANODE

I_G	V
-330 MA.	-18.9
-318	-15.8
-250	-11.9
-124	-10.3
- 65	-10.0
- 30	-10.0
0	-9.8
+ 68	-9.8
+ 150	-9.6
+ 250	-9.2
+ 355	-8.9
+ 495	-8.7



Dec 31, 1927
Edgerton & Church



Keepalive excited with d.c. from power supply.

110 v 60 cycle obtained from sine wave m-g set.

E	f	I
116.5	60.9	.477

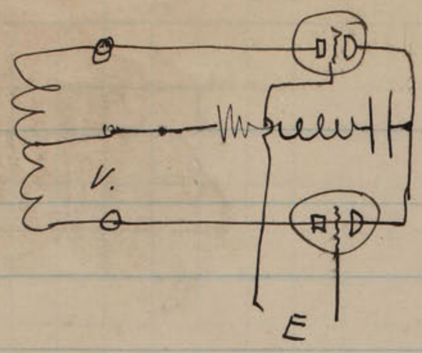
A.C.			GRID			D.C.			
V_p	V_s	I_s	V	I_G	DEG	V	I_{dc}	I_{ac}	
	446	0	220	0	51°	0	0	0	Grid tied with Resistance Inductive Load.
	446	— ?	220	—	105°	4	—	— ?	
	443	— ?	220	—	150°	33	.35	— ?	
	438	— ?	220	—	195°	97	1.10	— ?	
	436	1.22	220	—	240°	171	1.72	1.73	
	436	1.25	220	—	270°	172	1.88	1.75	
	446	0	220		48°	0	0	0	Grid tied with Auto. Increased Load. Inductive Load
	447	—	220		105°	1	—	—	
	443	—	220		150°	12	.49	—	
	419	~~2.54~~	220		195°	92	3.75	—	
	412	4.20	220		240°	155	6.30	—	
	412	4.24	220		270°	157	6.40	—	
	448	0	220		51°	0	—	—	Grid tied with Autotransformer Open Circuit ~~Resistance Load.~~
	448	—	220		105°	16	—	—	
	448	—	220		150°	78	—	—	
	448	—	220		195°	148	—	—	
	448	—	220		240°	178	—	—	
	448	—	220		270°	175	—	—	
	448	—	220		300°	160	—	—	
	448°	—	220		330°	135	—	—	

A.C.		Grid		D.C.	
V_s.	I_s	V.	Deg	V.	I_{dc}.
44.8	0	660?	85°	0	0
448	–	660	105°	0	–
448	–	660	150°	9	.35
427	2.0	660	195°	73	2.95
414	4.18	660	240°	154	6.30
414	4.27	660	270°	157	6.41

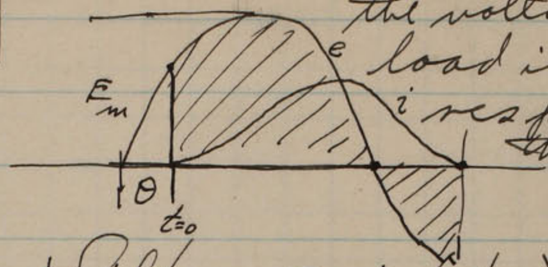
Inductive Load
Increased Grid Voltage!

Oscillographic tests show that angle reading on phase shifter is not correct.

Feb 17 1930
H. E. Edgerton



Assume no voltage drop in rectifier for first approx. that is the voltage across the load is large with respect to that across the rectifier.



$$L\frac{di}{dt} + Ri + \frac{1}{C}\int i\,dt = E_m \sin(\omega t - \theta)1$$ ← this voltage continues to act until the current becomes zero or the other anode takes the current.

$$CL\frac{di}{dt} + CRi + \int i\,dt = CE_m \sin(\omega t - \theta)1$$

Let $t = a\lambda$ $dt = a\,d\lambda$.

$$\frac{CL}{a}\frac{di}{d\lambda} + RCi + a\int i\,d\lambda = CE_m \sin(\omega a\lambda - \theta)\,1$$

multiply by $\frac{1}{a}$

$$\frac{CL}{a^2}\frac{di}{d\lambda} + \frac{RC}{a}i + \int i\,d\lambda = \frac{CE_m}{a}\sin(a\omega\lambda - \theta).\,1$$

Let $\frac{LC}{a^2} = 1$ or $a = \sqrt{LC}$

then $$\frac{di}{d\lambda} + R\sqrt{\frac{C}{L}}\,i + \int i\,d\lambda = E_m\sqrt{\frac{C}{L}}\sin(\sqrt{LC}\,\omega\lambda - \theta).\,1$$

let $R\sqrt{\frac{C}{L}} = k$.

$$\frac{di}{d\lambda} + ki + \int i\,d\lambda = E_m\sqrt{\frac{C}{L}}\sin(\sqrt{LC}\,\omega\lambda - \theta)\,1$$

$p = \frac{d}{d\lambda}$ $$pi + ki + \frac{i}{p} = A\sin(\omega_0\lambda - \theta)\,1$$ $A = E_m\sqrt{\frac{C}{L}}$, $\omega_0 = \sqrt{LC}\,\omega$.

$$\frac{i}{p}(p^2 + kp + 1) = A\sin(\omega_0\lambda - \theta)\,1$$

or in the charge form since $i = \frac{dq}{dt} = \frac{1}{a}\frac{dq}{d\lambda} = \frac{p}{a}q$.

$$\frac{p^2}{a^2}q + \frac{kpq}{a} + \frac{q}{a} = A\sin(\omega_0\lambda - \theta)\,1.$$

$$p^2q + kpq + q = \sqrt{LC}\,A\sin(\omega_0\lambda - \theta)\,1$$

April 5, 1930
H. E. Edgerton

Regulation-Angle Characteristics of a Thyratron with Inductive load

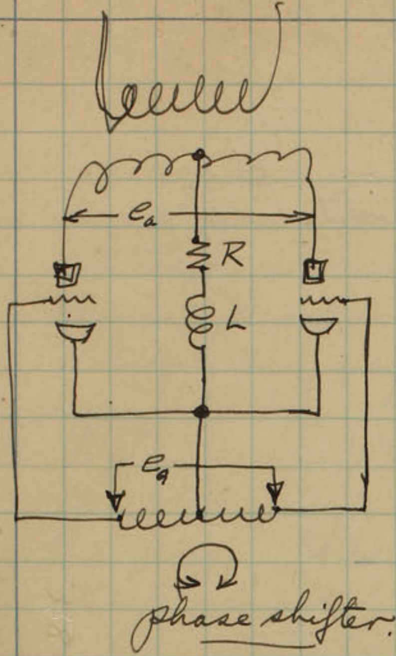
A thyratron which is grid controlled (angle) and feeds into a pure resistance circuit always has its load current and load voltage in exact proportion. This problem is treated in a research report that Mr. E. A. Church and the writer prepared in Dec. and Jan. 1928.

Inductance in the load circuit of a grid controlled thyratron gives a different curve of regulation voltage against angle (between the anode voltage and that of the grid). When the grid goes positive the current in the anode circuit starts. The inductance allows a certain rate of increase and the transient gives the same current as a sine wave of impressed e.m.f. impressed on a R L circuit (neglecting the non-linear rectifier circuit).

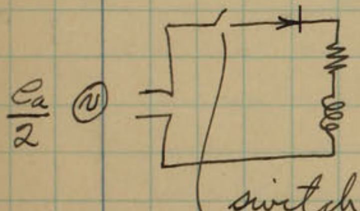
With a pure resistance load the current stops at the same time that the anode voltage does. However with inductance the current continues to flow and maintains the arc. Across the load, during the time the arc is maintained, the impressed e.m.f. from the circuit is <u>negative</u>. This cancels out ~~the~~ some of the positive voltage. Thus the regulated voltage-angle voltage curve will be steeper than with the resistance case. This can be seen on the preceding page on the diagram of instantaneous current and voltages.

L-R Circuits
V-Angle Curves.

Apr 5 1930
H. E. Edgerton



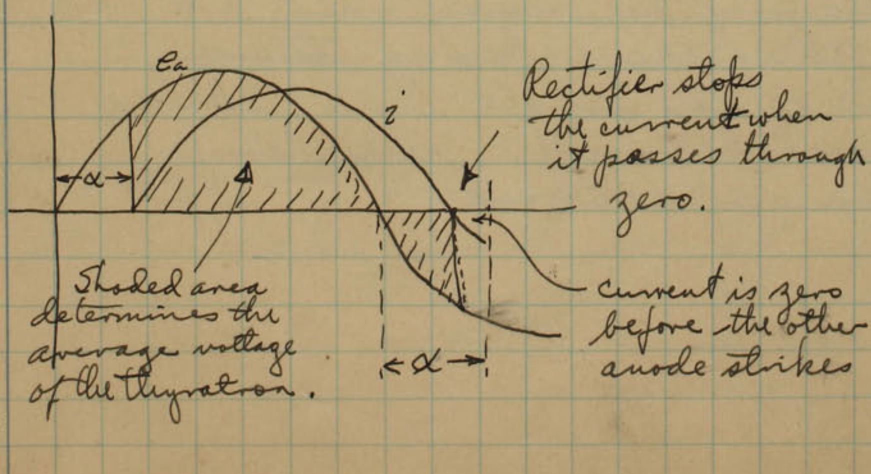
We will consider first the case where the inductance is small enough to not maintain the current continuously. that is, the current in the load circuit will be of pulses. this case is some what simpler since the initial boundary conditions are known when an anode starts to conduct.



switch closed at an angle which is that which exists between anode and grid voltages.

The electrical circuit to be considered is then as shown in the sketch to the left. the switch closes when the grid voltage becomes zero (or slightly positive). the rectifier characteristic limits the current flow to one direction as shown by the arrow. The switch opens at the instant that the current is zero and this represents the regain of control by the grid in the thyratron.

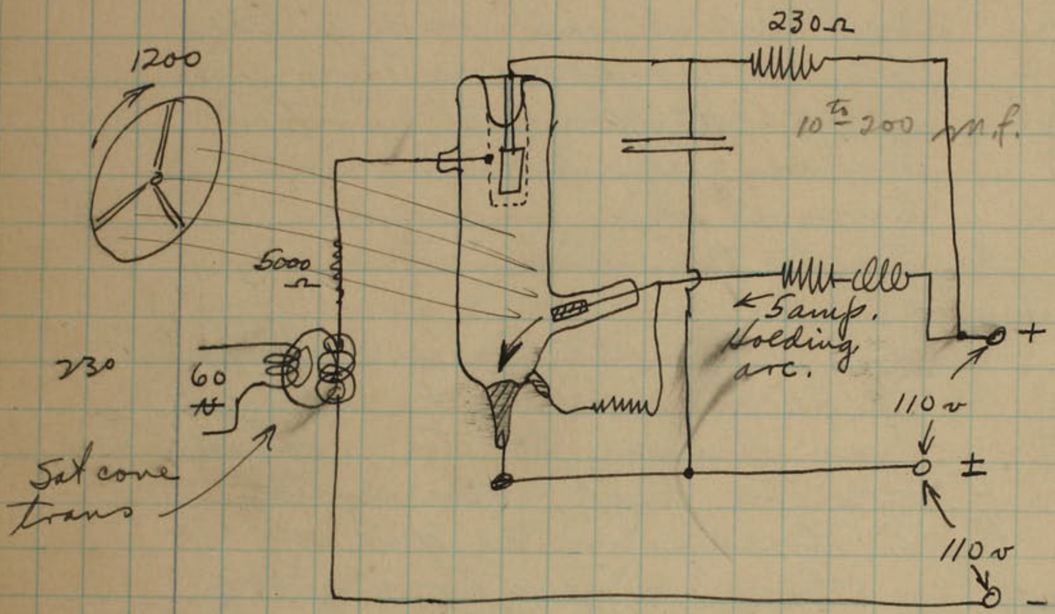
A d-c. voltmeter across the LR circuit will read the average voltage across these circuit elements.



Apr 5 1930
H. E. Edgerton

Stroboscope.

A thyratron tube of special design given me by Dr. Elder of the Research Lab of the G. E. Co. The following circuit was used to get stroboscopic light from the tube.



The grid is normally biased 110 volts by main shop. The transformer which is shown on the left is of special design. The magnetic path for the secondary is highly saturated so that the induced e.m.f. is very peaked.

This stroboscope was used to observe a thin white line on a black disc. The distinction was very good. The machine driving the disc ran at 1200 r.p.m. thus there being ~~there~~ three images of the single line, spaced 120 mechanical degrees. The lamp flashes 60 times a second.

Apr 11 1930
H. E. Edgerton
Hall.

Frequency Limitation of the Mercury Stroboscope

A General Radio oscillator was used to regulate the freq. Mr. Hall fixed up this circuit. It fed into the grid circuit same as the experiments of Apr 5. except the neg. bias of the grid was varied to fit the needs of the oscillator. With 110 volts, on the condenser freq. up ~~to~~ 1200 were reached with fair definition of the line. This line was a ~~x~~ radial white strip (about 1/8") on a 12" black disc. The disc rotated at 1200 r.p.m.

Gc* p.s.

For some tests 200 m.f. were used.

In the afternoon we put 220 volts on the condenser and varied the amount of capacity. For the high frequencies the constants of the condenser circuit were not fast enough for stroboscopic action.

With a high voltage on the condenser more energy can be stored in the condenser and discharged more quickly (due to ~~low~~ small capacity for equal light). However the resistance that blocks the circuit must be larger and thus the time constant of the circuit that charges the condenser is slower.

We showed I believe that this tube would give satisfactory stroboscopic action from 20 cyc/sec. to 700 ± cyc./sec.

A large Western Electric cone was excited with 150 volts 60 cyc. a.c. and the stroboscope was run at about 59 or 61 cycles. The surface of the cone could be seen to warp and oscillate at a slow speed. We could see the ~~x~~ vibration patterns of the surface. Prof Bowles saw this and was interested.

1 KVA at 220 ~ 60 ~

$X_c = \frac{1}{2\pi f C}$

$1 = \frac{V^2}{X_c} = 220^2\, 2\pi f C$ $\quad C = \frac{1000}{220^2\, 2\pi 60} = .552 \times 10^{-6}$ farads

55 m.f.

April 21 1930
H. E. Edgerton

Stroboscope -

Previous work to date (Apr. 21, 1930) which I have on loose sheets were today glued into this book on the following pages 33 to 38.

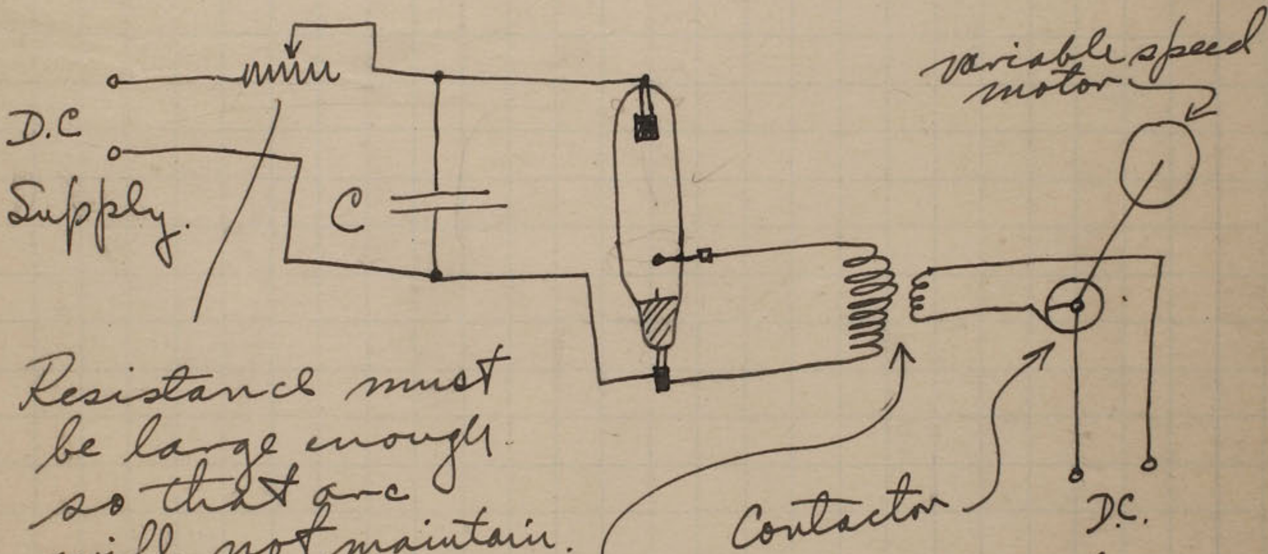
The circuit on page 35 was used successfully as an open-house display in the spring of 1929. Mr. Robert V. Kleinschmidt and Mr. Ben B. Folger of Arthur D. Little Inc. came over and I demonstrated the setup to them the week after open-house. They were interested in a slow speed stroboscope. I gave them a price which was high because of the difficulties I expected in the construction and test of the device.

The main disadvantage of the circuits on pages 34, 35, 37 is the fact that a contact on a rotating device must carry the entire current which gives the light. The first contact that touches gets a heavy surge of current which raised havoc with the metal by burning. Part of this trouble can be eliminated by inserting a small amount of inductance which cuts off the rapid rise of current. It also tends to make the current oscillatory.

The circuits of pages 33 and 36 are better since the transient is tripped by the switching circuit. Page 33 circuit does not have a holding arc. The high potential from the spark coil may set off the transient by being connected to a tin foil around the cathode outside the glass. A surge of current discharges the condenser and the resistance to the line keeps it from ~~building up~~ maintaining the spot.

Cambridge Mass.
May. 28. 1929.

Method of operating a mercury arc tube as a ~~Rot~~ Stroboscope.



Resistance must be large enough so that arc will not maintain itself.

Spark coil giving high voltage to break down tube and start arc.

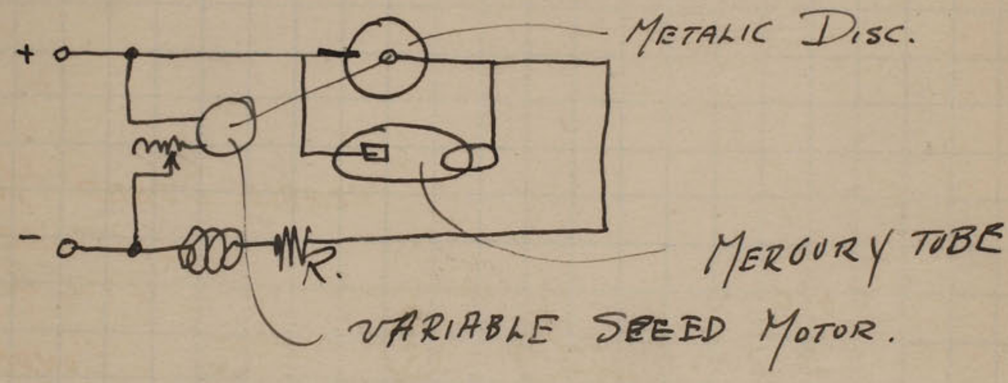
This circuit was shown to me by H. E. Edgerton on May 28, 1929.

Charles Kingsley Jr.
Cambridge, Mass.

STROBOSCOPE

This describes an idea for the utilizing of a-n ionized mercury vapor tube as a means of obtaining stroboscope action.

A current of sufficient magnitude to give enough light is sent through the mercury tube at definate periods of time. This is accomplished by having a variable speed motor drive a metalic disc. This disc has a small insulating segment on its rim. A narrow brush ~~///~~ makes contact with the rim of the disc. When the insulated sector and the brush are together the current that normally passes from brush to disc is shunted into the mercury tube.



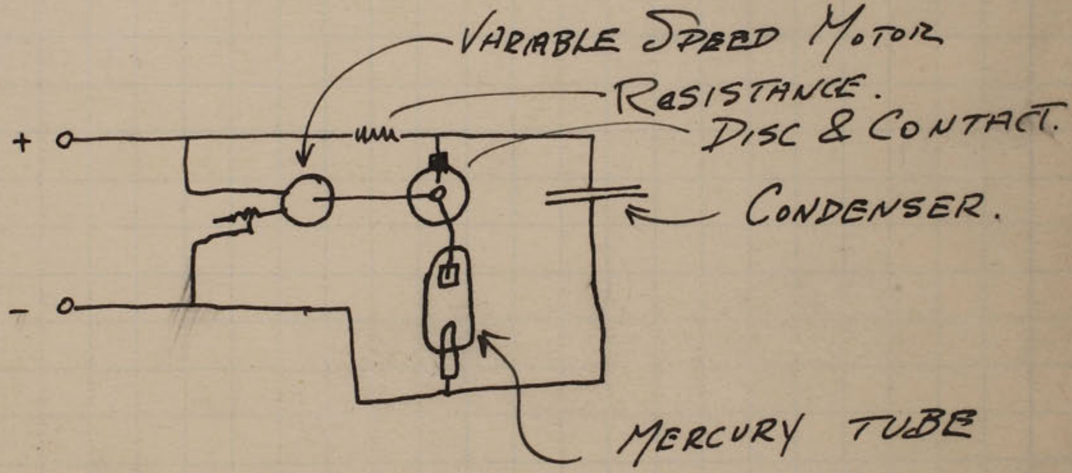
Witnessed in operation, May 16, 1929

Truman S. Gray
Cambridge, Mass

MERCURY STROBOSCOPE.

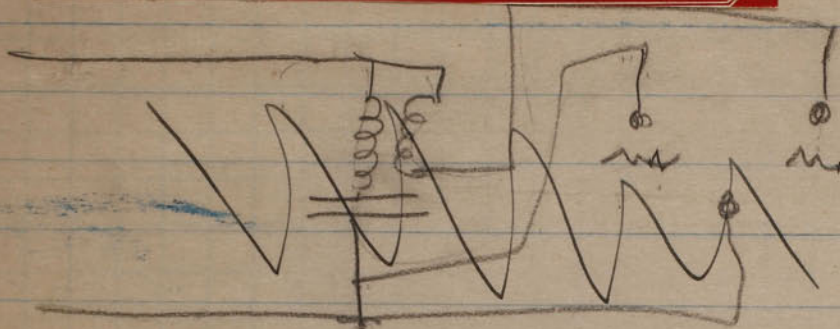
A stroboscope using a mercury vapor tube is described herein. The light from such a devise is much more suseptable to photography than other types of stroboscopes using neon lamps.

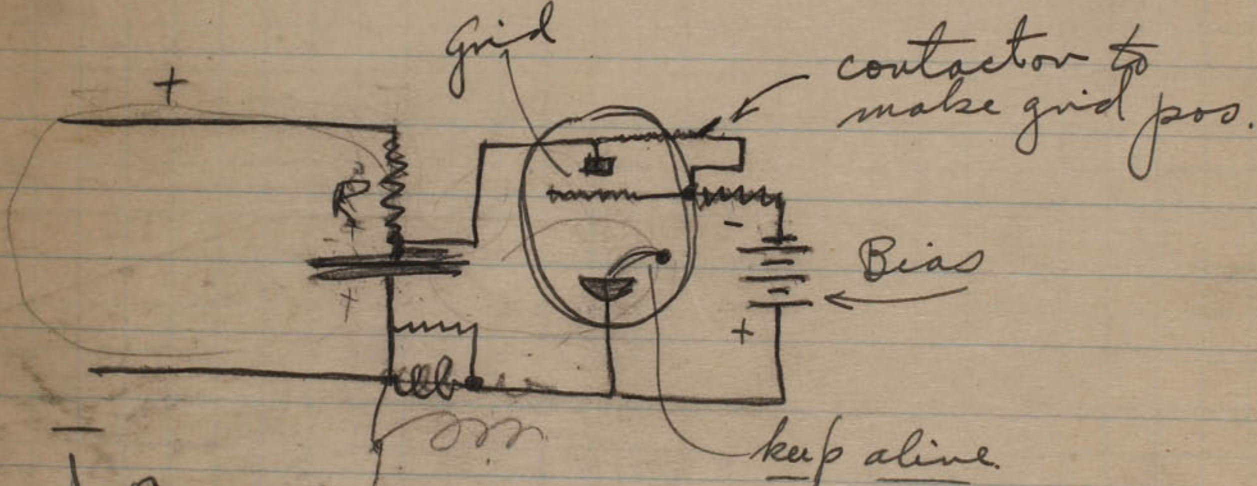
The method of obtaining stroboscopic action is to discharge a condenser through the ionized mercury vapor at periodic times. A small variable speed motor driving an insulated disc with one small contact and brush furnish the interupting of the circuit at definite intervals of time. A resistance is put between the condenser and the source of constant potential that is used for a supply. This limits the current taken by the condenser during the time that it is being charged.

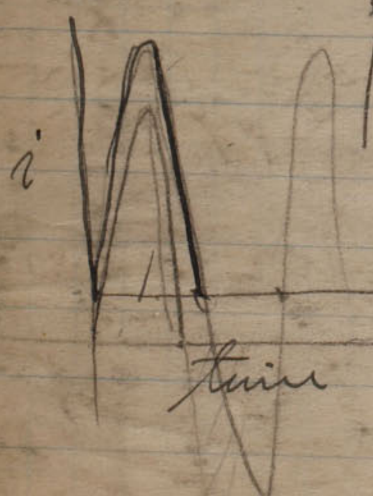


The source of d-c. voltage must be 220 volts or more in order to have the discharge fast and strong enough.

Witnessed in operation, May 16, 1929
Truman S. Gray
Cambridge, Mass.

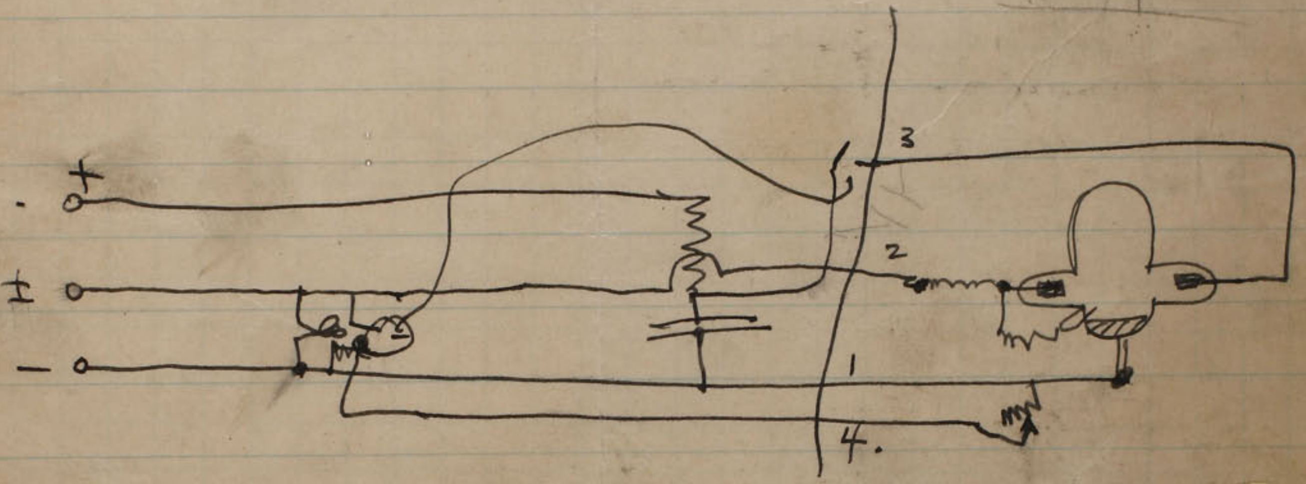




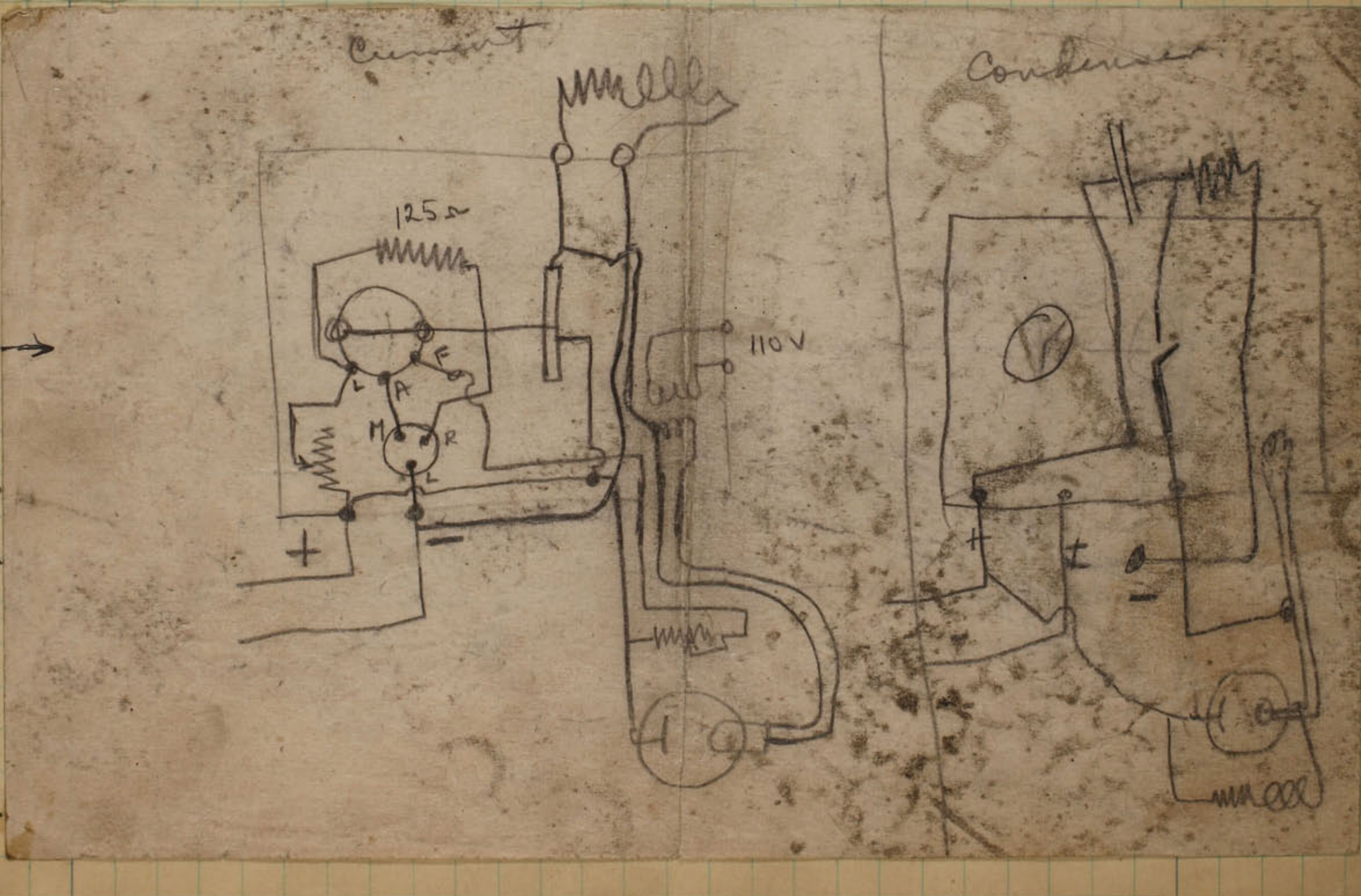


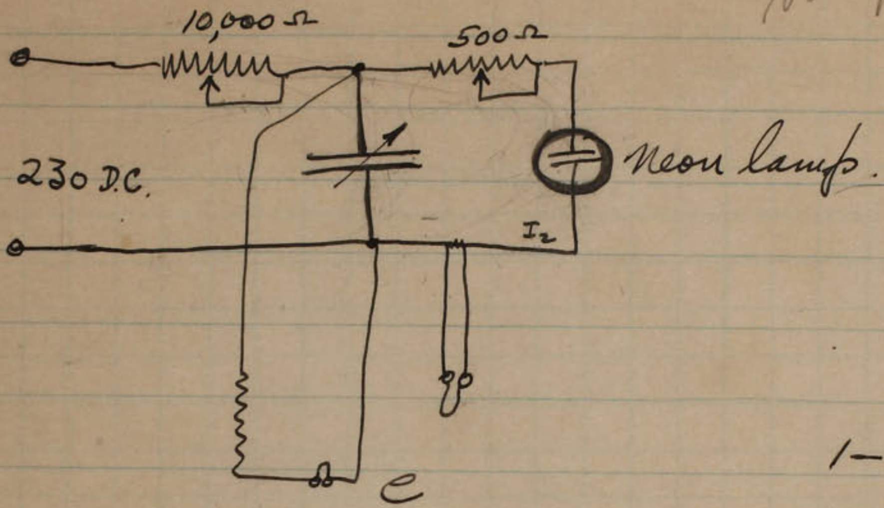
This circuit was shown to me by H. E. Edgerton on May 28, 1929
Charles Kingsley Jr.
Cambridge, Mass.

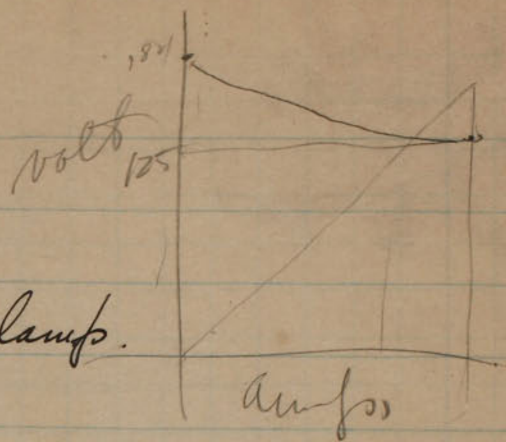
This circuit was used for a open-house demonstration in 1929.



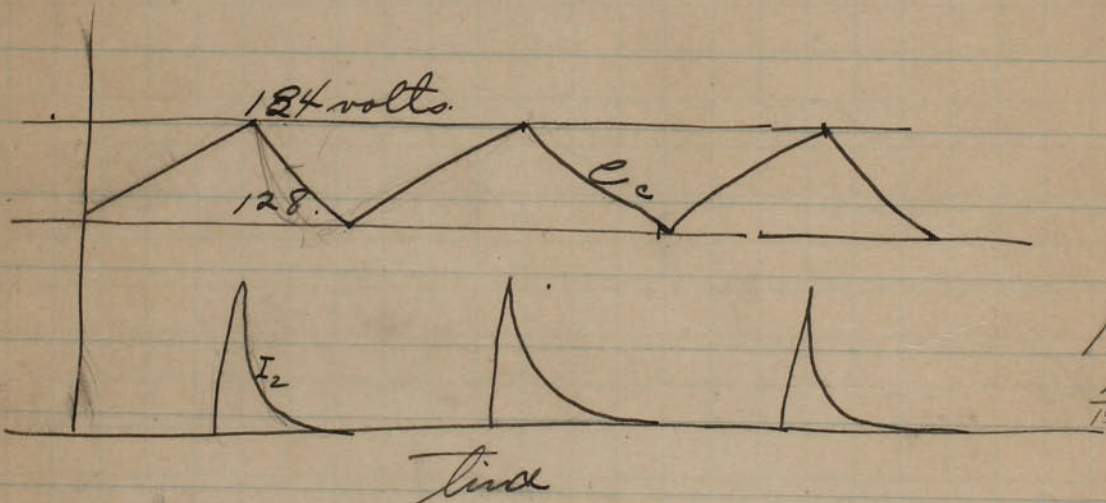
Wiring diagram for an experimental hot cathode ~~tube~~ stroboscope for an open-house display. This was not used due to the darkening of the bulb.







1 – 10,000 ohm.
1 – 500 ohm.
condenser.



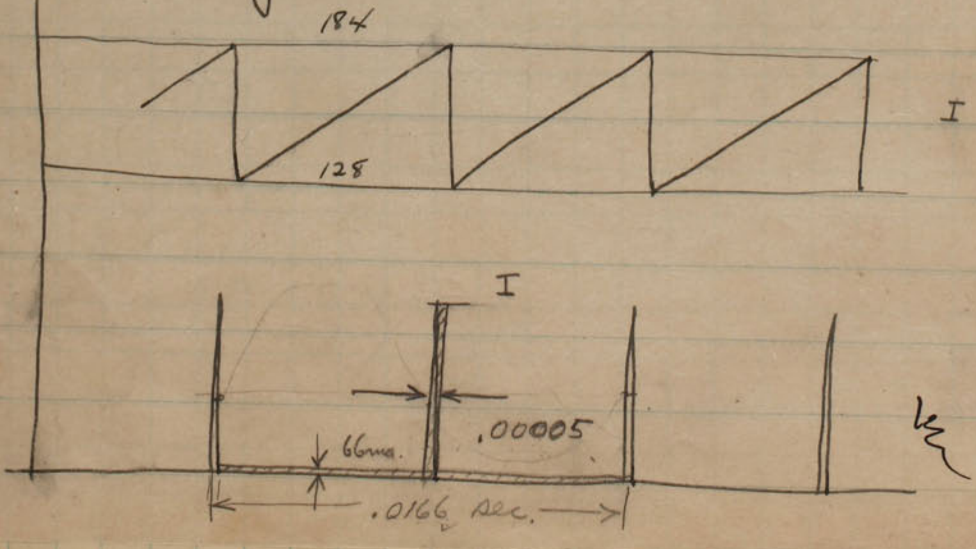
10 watts.

$\frac{10}{150} = .066$ mils

66 mils

Reducing R_2

60 cycle.

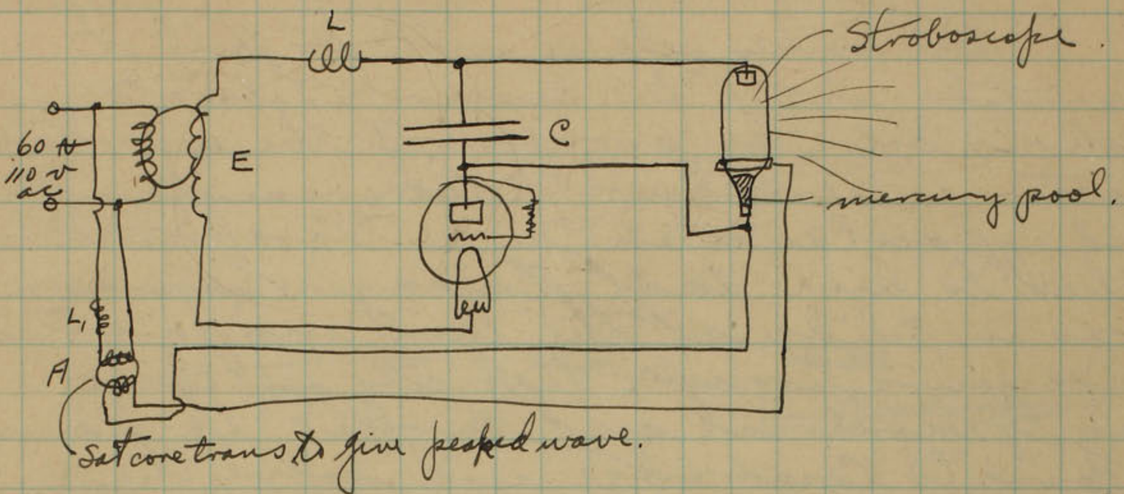


$I = \frac{.066 \times .0166}{.00005000}$

$= 21.8$ amps.

A-C operated Stroboscope

April 21 1930
H. E. Edgerton.



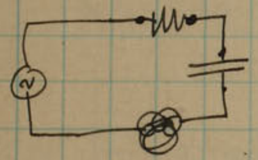
The transient through L C and the rectifier should last about 1/8 or 1/4 of a cycle. It should not overload the hot cathode of the rectifier and should allow the stroboscope to go out after the surge.

The transformer A should give high enough voltage to break down the ~~to~~ stroboscope and start the cathode spot.

H. E. Edgerton
May 26 1930

A-C on circuit of R C and iron-core reactor

Dr. Suikes who is with Dr. Hull at Schenectady in the G. E. Research Laboratory wishes to solve the problem of the iron-core reactor in series with ~~the~~ resistance and capacitance on the Integraph. I talked to him last Friday when I was in Schdy at the time my parents were going through that city on their way to Montreal and Europe. He plans to come to Cambridge and solve the problem if it is possible. I sent him the pamphlets which describe the machine and the type of problems that it handles, today.

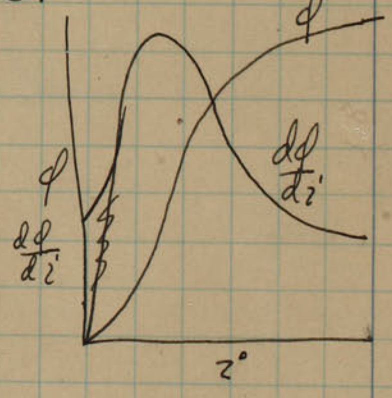


Steady state.

$$E \sin \omega t = Ri + \frac{1}{C}\int i\,dt + N\frac{d\phi}{dt}$$

Between ϕ and i there is a single valued functional relation given by the magnetization curve of the material composing the core of the coil.

$$\frac{d\phi}{dt} = \frac{d\phi}{di}\cdot\frac{di}{dt}$$



which gives

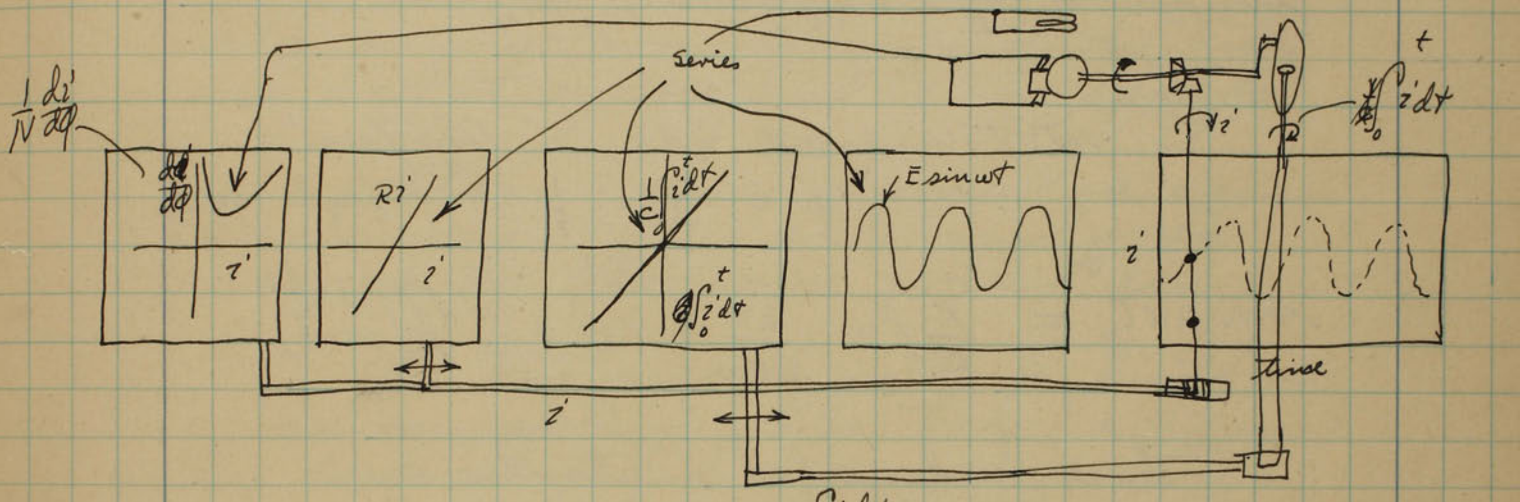
$$E \sin \omega t = Ri + \frac{1}{C}\int_0^t i\,dt + \left[N\frac{d\phi}{di}\right]\frac{di}{dt}$$

note that $\frac{d\phi}{di}$ is a variable with i. It has a numerical value for each value of current and changes as the current changes. It is a <u>variable coefficient</u>.

Rewriting $\left[N\frac{d\phi}{di}\right]\frac{di}{dt} = E\sin\omega t - Ri - \frac{1}{C}\int_0^t i\,dt$

Integrating both sides ~~with time~~ after separating.

$$\int_0^i \frac{di}{dt} = i = \int_0^t \frac{1}{\left[N\frac{d\phi}{di}\right]}\int_0^t \left[E\sin\omega t - Ri - \frac{1}{C}\int_0^t i\,dt\right]dt.$$



Since $\frac{1}{N\frac{d\phi}{di}}$ is not a function of time? it may be either in or out of the integral sign. No!

If a standard magnetization curve may be used it is possible to reduce the numer of constants and so make the solutions apply to any problem. List of constants.

R,	C	N	E	ω	φ-i function
1	2	3	4	5	6

Six ~~are~~ constants which take different values with different problems.

Let λ = a new variable which will be equal to time ~~multiplied~~ divided by some unknown constant "a".

~~$t = a t$~~

$t = a\lambda$

$$\sin \omega t = \frac{R}{E} i + \frac{1}{CE}\int_0^t i\,dt + \left[\frac{N}{E}\frac{d\phi}{di}\right]\frac{di}{dt}$$

changing variable $t = a\lambda$, $dt = a\,d\lambda$ $\qquad \frac{d}{dt} = \frac{1}{a}\frac{d}{d\lambda}$

$$\int_0^t dt = \int_0^{a\lambda} a\,d\lambda =$$

$$\sin a\omega\lambda = \frac{R}{E} i + \frac{a}{CE}\int_0^{a\lambda} i\,d\lambda + \left[\frac{N}{E}\frac{d\phi}{di}\right]\frac{di}{a\,d\lambda}$$

Let $a\omega = 2\pi$ $\qquad$ 1 cyc./sec.

$a = \frac{2\pi}{\omega} = \frac{1}{f}$ $\qquad$ f = freq in cyc/sec.

$$\sin 2\pi t = \frac{R}{E} i + \frac{2\pi}{CE\omega}\int_0^{\frac{2\pi}{\omega}\lambda} i\,d\lambda + \left[\frac{N}{E}\frac{d\phi}{di}\right]\frac{\omega}{2\pi}\frac{di}{d\lambda}.$$

three fundamental constants.

Let

$\underline{\underline{A}} = \frac{R}{E}$

$\underline{\underline{B}} = \frac{2\pi}{CE\omega} = \frac{1}{CEf}$ since ⟶ $\omega = 2\pi f$

$\underline{\underline{C}} = \frac{Nf}{E}\frac{d\phi}{dt}$ = a function of i.

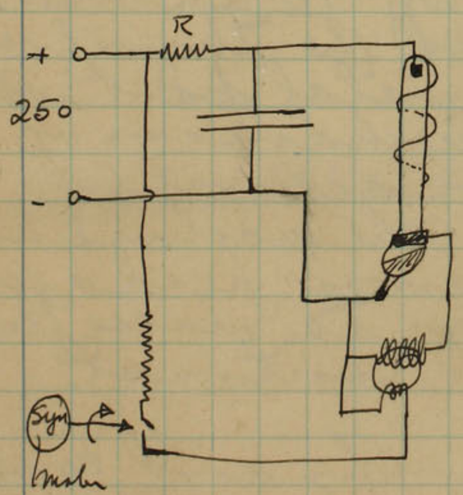
Stroboscope for Dyn. Lab.

May 27 1930
H. E. Edgerton

Mr. K. D. Beardsley who has been developing a mercury arc stroboscope for use in the dynamo laboratory found trouble with flickering.

We tried to eliminate this with a wire wound around the tube and had it connected to the spark coil. Later it was connected to +250 volts and also connected again to the anode. This external grid reduced the flicker a great deal.

The stroboscope is to be built in a box on casters. The tube, a 22 inch a-c Cooper Hewitt lamp will be the source of light. It will be ignited or started with a spark coil which is interrupted with ~~a spark coil~~ an automobile distributor driven by a synchronous motor.



Cooper Hewitt tube.

A two way switch is to be on the unit. One way gives the tube the regular a-c connection in order to warm it up. The other switches on the synchronous motor contact maker and gives 60 cycles stroboscopic action.

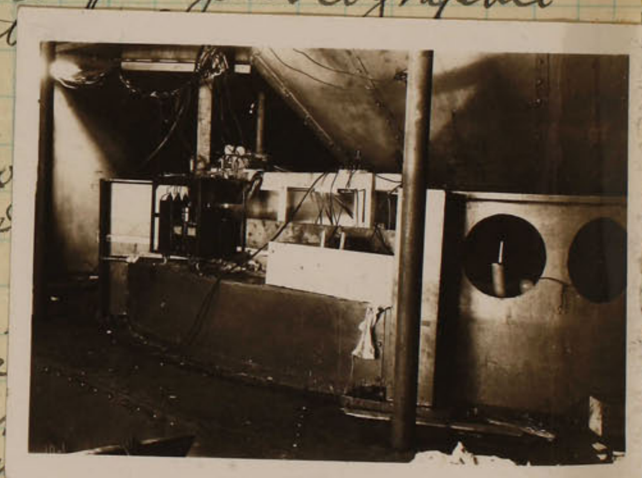
Sept 16 1930

Stroboscope.

H. E. Edgerton.

1SEC. F 4.5.

I constructed a strob
be used for observation
electrical angle of dis
of the generators of the 15
developement of the New En
company located near
and East ~~Verm~~ Barnet Ve
Previously I had go
a G.E. single phase tube
~~and~~ to measure the angle of a
5 kw induction machine. Mr.
Spencer brought Mr. L. Thurston
(movie camera man) over and he
took some shots with 1.9 lens
and 12 frames a second. He said that
the light was sufficient for photographic
purposes. (Panchromat
used.)



On thursday the 4th o
went to the 15 mile falls
was constructed so that
rotor of # 2 generator
Upon this was mounte
Below it was a sheet
was part of the fan
the rotor. Upon this were accurately
located 52 white lines
52 poles) adhesive tape
stuck to the lines in ord
photographs have mor

The windage was te
with a cold spell ma
conditions for the thyr
circuit that I was u
transformer could not
voltage to trip the circuit. After experi
some I got a 110-440 volt pot transformer and

Sept 16 1930 Stroboscope.

H.E. Edgerton.

I constructed a stroboscope to be used for observation of the electrical angle of displacement of the generators of the 15 mile falls developement of the New England Power company located near St Johnsbury and East ~~Verm~~ Barnet Vermont.

Previously I had connected up a G.E. single phase tube in the lab ~~and~~ measured the angle of a 5 kw induction machine Mr Spencer brought Mr. L. Thurston (movie camera man) over and he took some shots with ".19 lens and 12 frames a second. He said that the light was sufficient for photographic purposes. (Panchromatic film was used)

On thursday the 4th of Sept I went to the 15 mile falls plant. A platform was constructed so that it cleared the rotor of #2 generator by 1/2 an inch. Upon this was mounted the thyratron. Below it was a sheet metal part which was part of the fan mechanism of the rotor. Upon this were accurately located 52 white lines (the machine has 52 poles) adhesive tape arrow heads were stuck to the lines in order to make the photographs have more contrast.

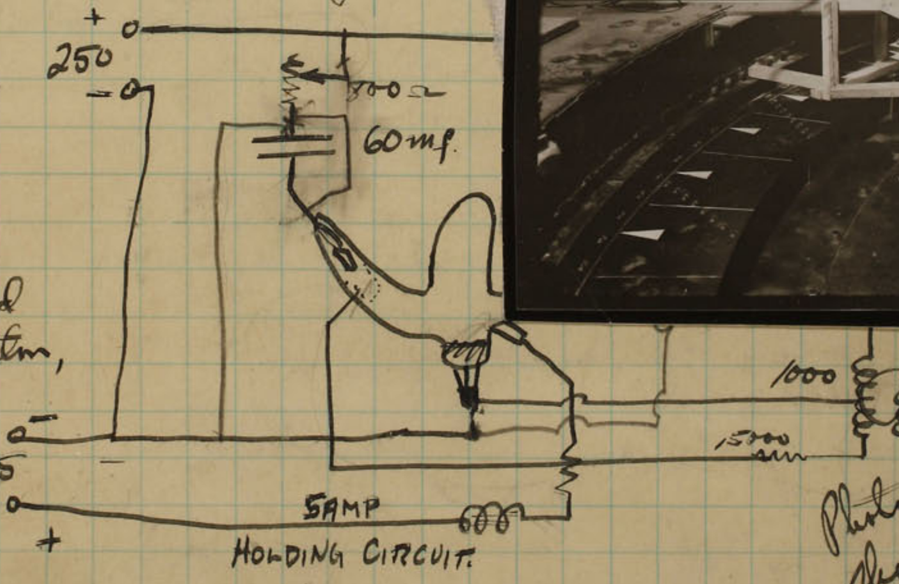
The windage was terrific and combined with a cold spell made adverse operating conditions for the thyratron with the circuit that I was using. The grid transformer could not supply enough voltage to trip the circuit. After experimenting some I got a 110-440 volt pot transformer and

found that it gave much better operation.
I returned to Boston on the 8th of Sept.

On the 12 Spencer again called and wished me to bring up the oscillograph and an assistant to watch the stroboscope. Mr. Sullivan went with me.

I took a 1000 volt plate ~~tr~~ transformer which had a mid tap, thus I could use both tubes in opposition. 15000 ohms was put in the grid circuits where I used 5000 before. This was increased because the 5000 ohm resistors could not stand the current.

Circuit for



This circuit worked very satisfactorily. Was seen by Oliver, Dillard, Spencer, Thurston, Fisk, Sullivan, Patterson, Coe, Bankser, Treat, Lee and others.

Photograph showing arrows on the ~~poles~~ and the framework supporting thyratrons

If the grid impedance is put in the neutral leg the operation of the grid transformer will be somewhat different. It might be some advantage to use two grid transformers ~~a~~ and a neutral resistance to get favorable action.

Moving picture of system disturbances were taken. I returned to Boston with Sullivan on Sept 16, 1930. today. Had a great time.

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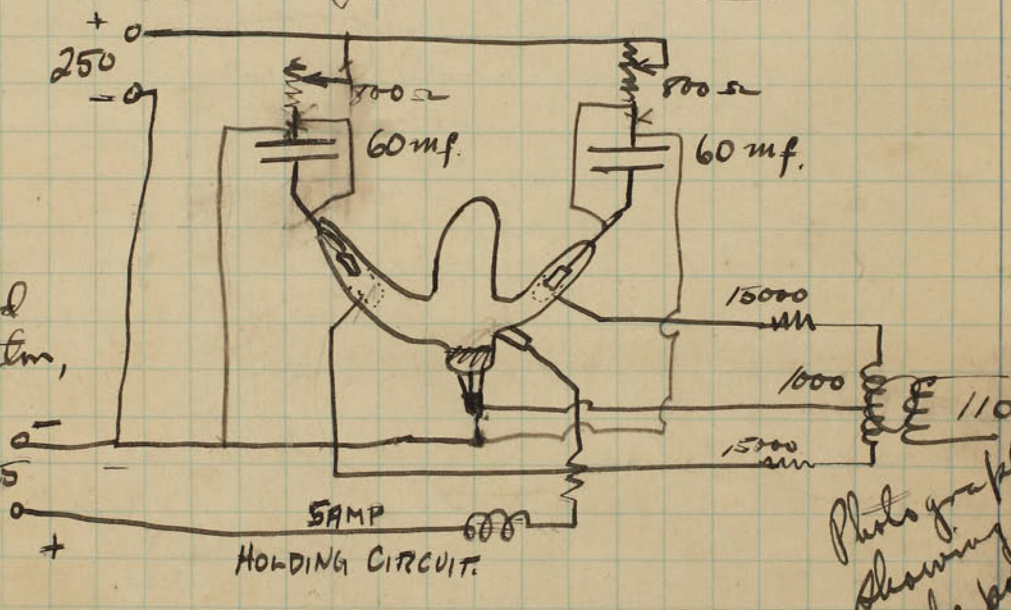
No 2.
mile Fal
Sept 1930
scope test

Circuit for stroboscope

This circuit worked very satisfactorily. Was seen by Oliver, Dillard, Spencer, Thurston, Fisk, Sullivan, Patterson, Coe, Bandeser, Treat, Lee and others.



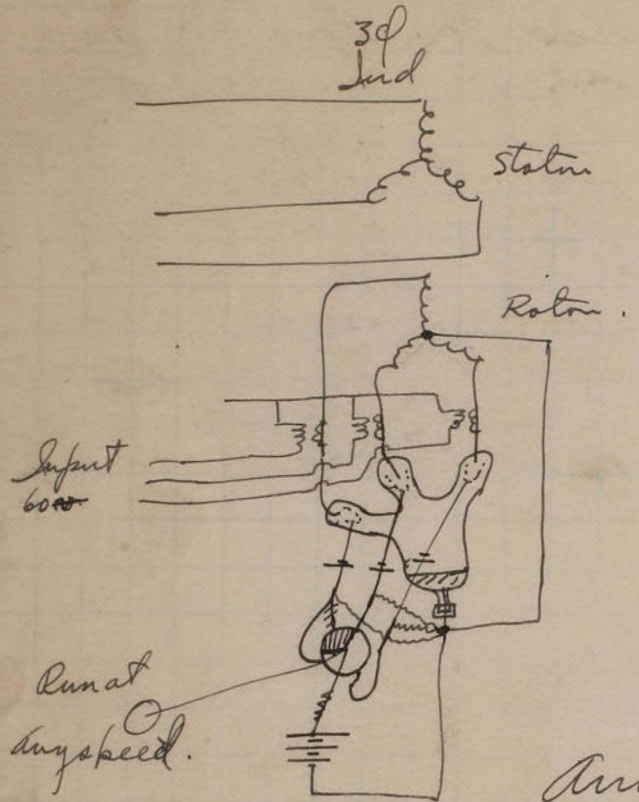
Photograph showing arrangement and the ~~poles~~ framework supporting thyratrons

If the grid impedance is put in the neutral leg the operation of the grid transformer will be somewhat different. It might be some advantage to use two grid transformers, ~~&~~ and a neutral resistance to get favorable action.

Moving picture of system disturbances were taken. I returned to Boston with Sullivan on Sept 16, 1930. today. Had a great time.

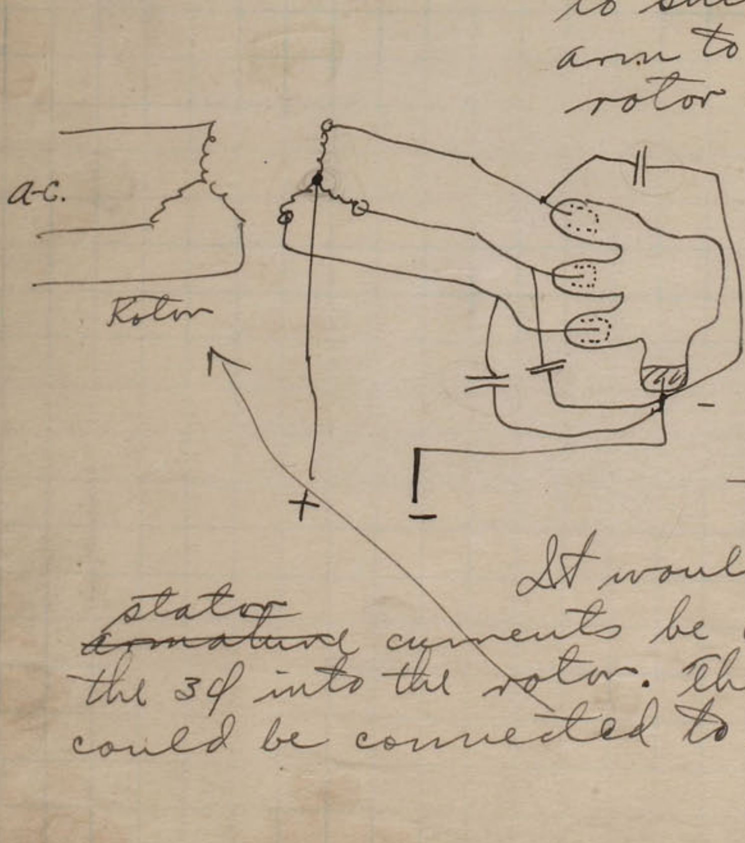
Glued in Sept 29 1930.

H. Edgerton.
Nov. 14.1929



The disadvantage here is that the rectifier works single phase on a heavy inductive load.

Another scheme would be to shift d-c from one arm to another in rotor circuit. The condensers will help the arc to transfer from one phase to the next. The more rotor phases the better such a motor will operate.



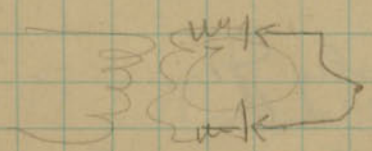
It would be best to let the ~~armature~~ stator currents be commutated and put the 3φ into the rotor. Then an anode arm could be connected to each coil.

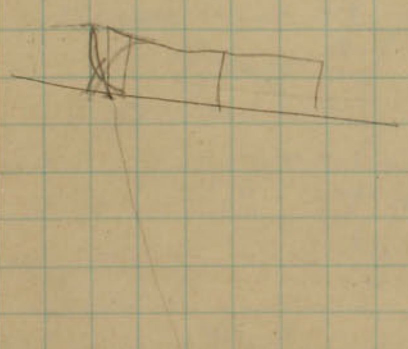
Sept 29 1930
H. E. Edgerton

Invertor

Invertors that give single phase power will always need to have energy storage properties such as condensers and inductances or the flow of d-c will be objectional.

Polyphase invertors however should have particular advantages for the reason that power can be transferred gradually from one phase to the next and thus draw ~~only~~ a continuous flow of energy, no storage device being needed.

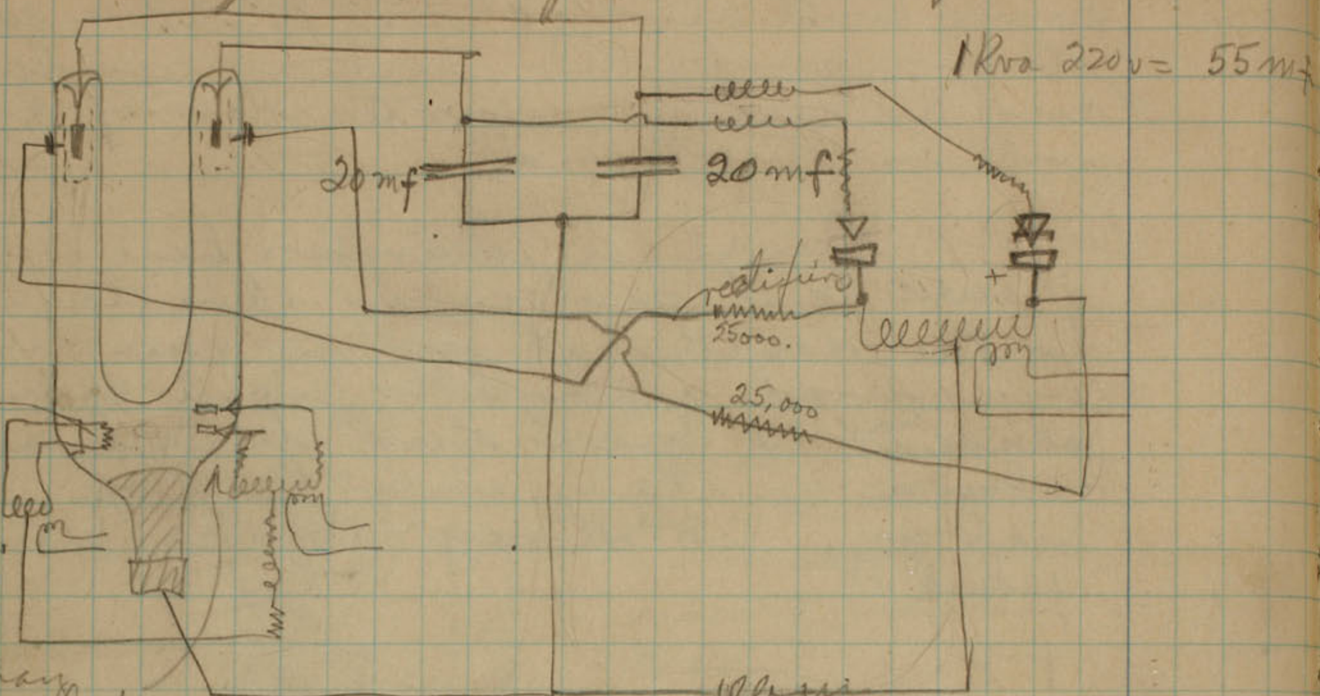




Sept 30 1930
H. E. Edgerton

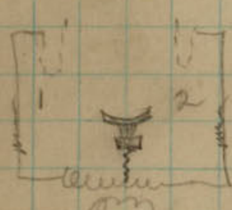
Stroboscope Circuit
for A.C. operation 120 flashes/sec.

1 kva 220v = 55 mf



Tot filament to supply ionization.

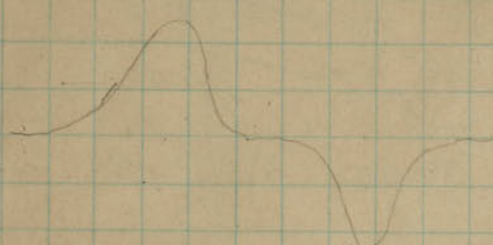
The other anodes may not be needed?



There is an advantage to putting resistance in the neutral circuit.

Charles Kingsley Jr.
Oct 2, 1930.

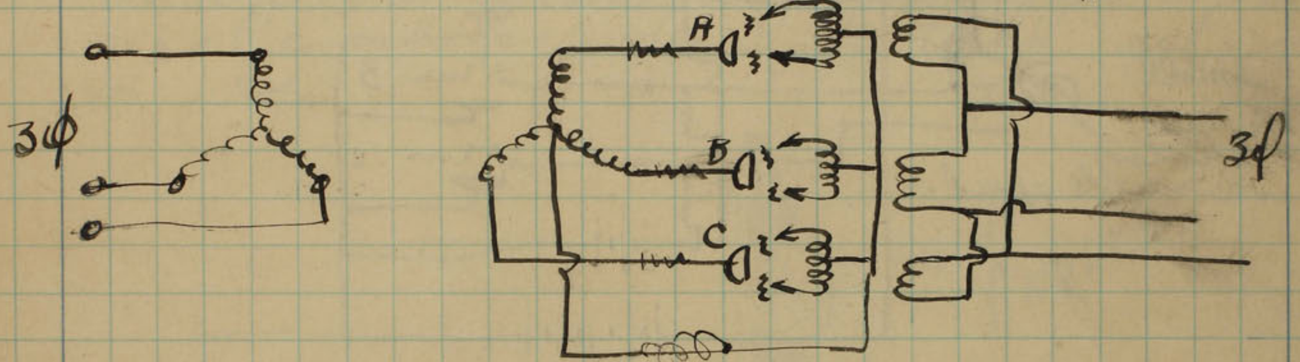
H. L. Hazen
10-2-30



Oct. 2, 1930.
H. E. Edgerton

Speed Regulation of A-C Motors by means of controlled Rectifiers.

The motor used is a wound rotor induction motor. The winding on both sides of the gap are to be polyphase. One winding will be fed by alternating current (polyphase) and thus set up a rotating field the other winding if fed with d-c will cause the motor to run synchronously. The d-c is in one winding only.



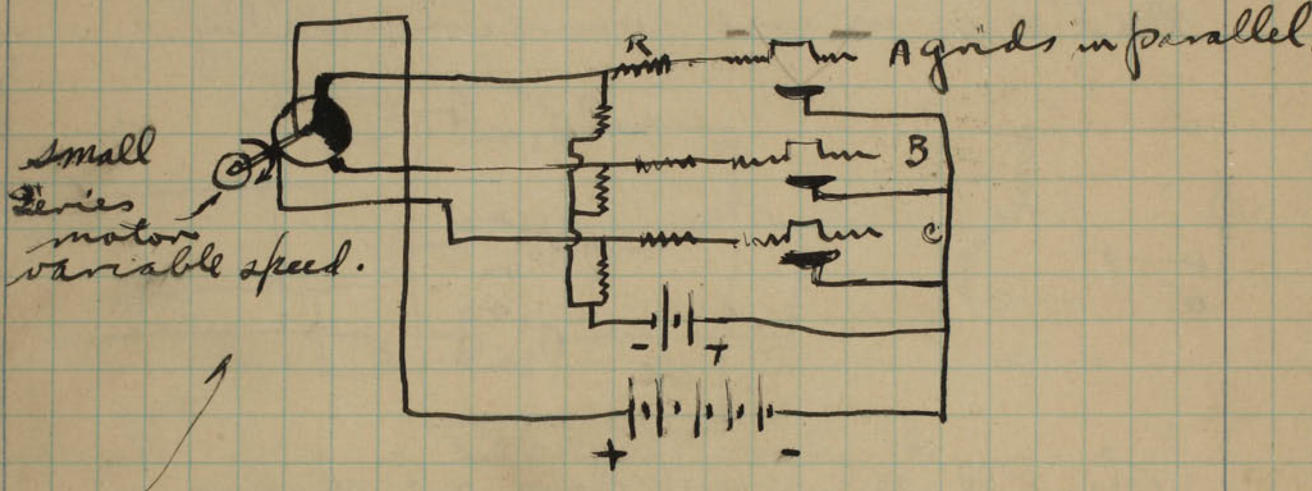
The full wave rectifiers as shown in the sketch (A, B, C) are able to supply d-c to each of the ~~rotor~~ phases. There is no limit to the number of phases.

Now if the phases are fed in rotation at a certain frequency the magnetic field that they produce rotates at a corresponding speed with respect to the rotor. This field will tend to stay in step with the rotating field due to the winding on the other side of the gap. The rotor will run at a speed which corresponds to the sum of the frequency of the supply and the frequency of field transfer or it will run at a frequency which corresponds to the difference of these frequencies.

By this means the rotor can be made to operate at speeds both above and below the synchronous.

cont

The function of the grids in the thyratron rectifiers is to control their operation. The grids may be made positive in rotation by means of a ~~[illegible]~~ small switch. A more satisfactory scheme would be to change the phase of a-c on the grids such that the change of field from one phase to the other would be gradual.



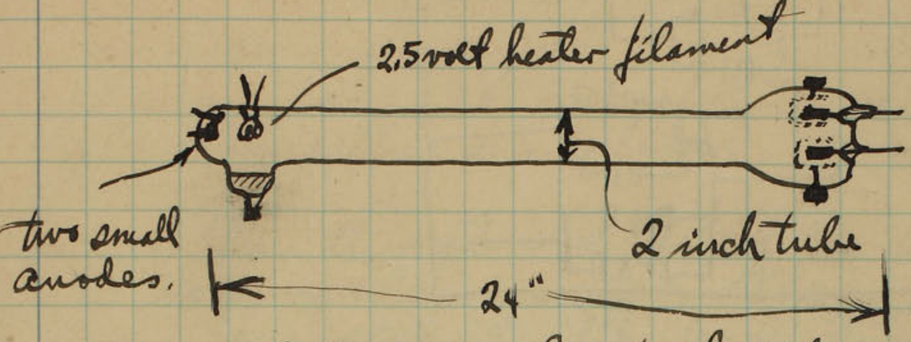
The contactor switches the field from one phase to the next by making the grids + in rotation.

Charles Kingsley Jr.
Oct 2, 1930

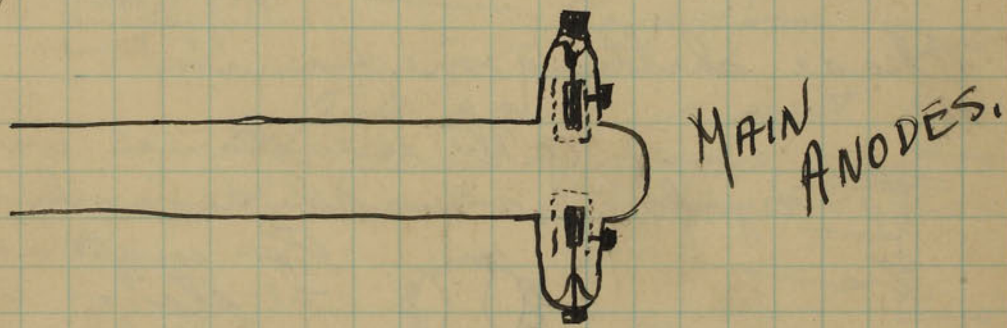
H. L. Hazen
10-2-30

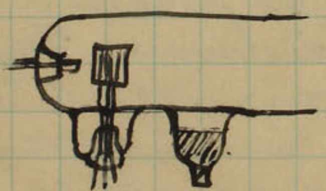
Stroboscope

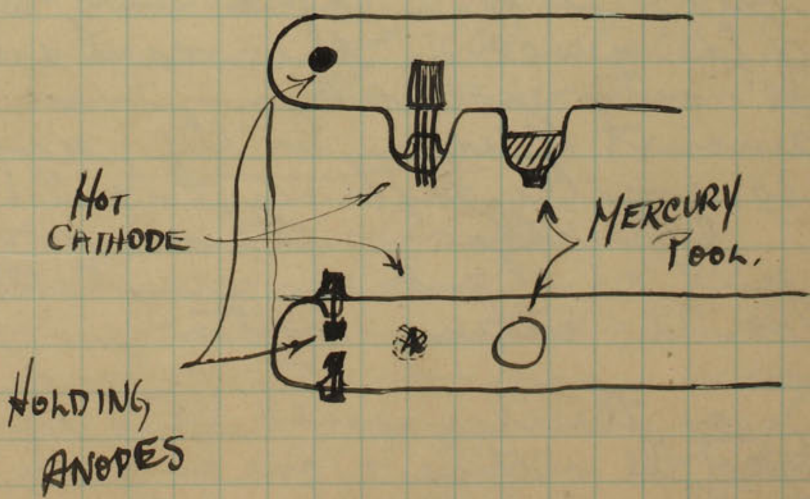
October 11, 1930
H. E. Edgerton



This will be used with the same circuit as shown on page 48. A high resistance connection will probably be put between the mercury pool and the heater filament in order to establish proper potential relationships when the tube gets ready to fire.







12" Disc rotating $\frac{3600}{60}$ r.p.s.

$60 \times \pi 12 = 2260$ inch sec.

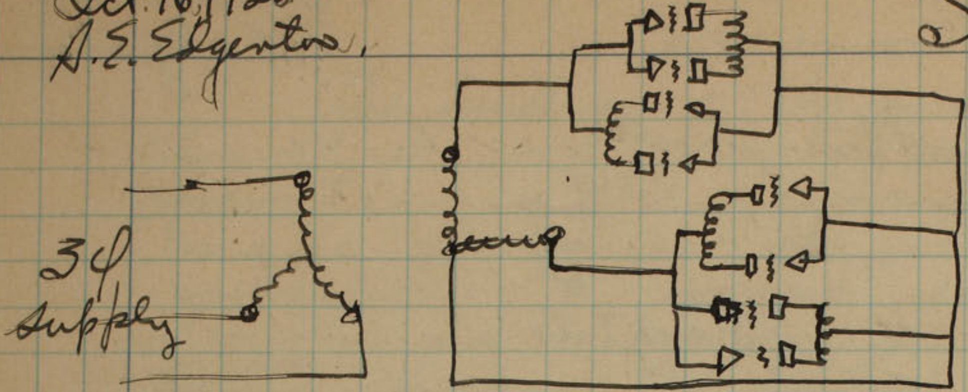
$\frac{1}{2}$ inch $= 222 \times 10^{-6}$ sec.

$\frac{1}{8}$ inch $= 55.5 \times 10^{-6}$

$\frac{1}{32}$ inch $= 14. \times 10^{-6}$

Oct. 16, 1930
A. E. Edgerton.

Speed Control.



A rotating field will be set up by the 8 thyratrons feeding into the two phase rotor circuit. A mechanism will shift the rectification from phase to phase so that the resultant speed is constant in magnitude and rotates at a constant speed.

Phase shifting mechanism

The inductance will be varied periodically. For instance take the stator winding of a small machine.

Make the rotor of laminated iron. As the rotor rotates there will be a great difference in the reactance because the rotor is unsymmetrical and the amount of iron in the magnetic path is greatly different in the two cases.

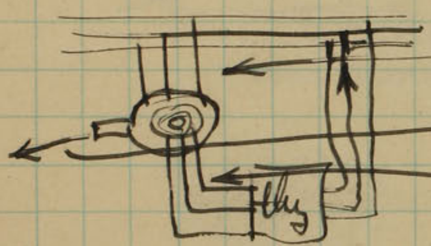
Another method would be to put a short circuited single phase winding on the ~~other~~ rotor circuit.

The idea would be to block completely six ~~two~~ of the rectifiers (one on each phase). Then the phase shifters (90 electrical degrees in time) would transfer the rectified current from one phase to the next at slip frequency. At ~~that~~ time the transfer was complete, then another would be immediately started, etc.

Cont.

Using two full wave rectifiers on each phase makes it possible to allow current to flow in either directions.

The thyratrons may be thought of as a frequency converter. They take power from the rotor at slip frequency and pumps it back into the lines at standard frequency (when the machine operates as a motor).



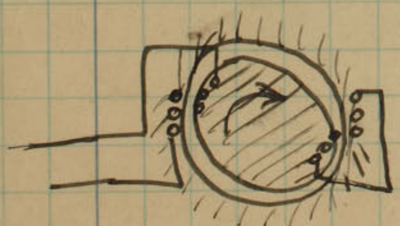
Power to motor = 1.0

Shaft power ≅ $1.\times(1-s)$.

Power from rotor ≅ $1\times s$.

this power is sent back into the lines by means of the thyratrons which act as a frequency converter.

If the machine is to be run above speed then power must be put in the rotor circuit. The power that comes out of the shaft is the sum of the stator and rotor power − the I^2R and core losses.



Variometer for ~~shifting~~ changing inductance.
A capacity in series and enough to give near resonance will give large phase shifts for small changes of angle of position of the rotor.

Oct 24 1930
H. E. Edgerton.

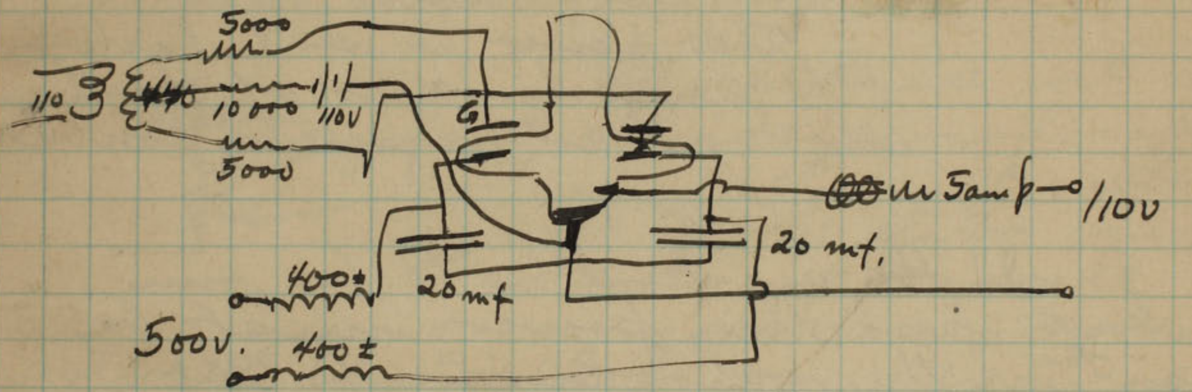
Stroboscope tests.

Spencer of the N.E. Power Co came over with Fish and Thurington - the last two who are photographers for the N.E.P. Co.

The stroboscope was set up to as simulate as closely as possible the 15 mile falls job.

A f3.5 movie camera (35 mm) that belongs to the institute was set up above the disc about 3 or 4 feet.

The ~~beat~~ best circuit used was



5 frames per second
f. 3.5 lens.

Notebook Number: T-1

Scanning and Separation Record

____unmounted photograph(s)

1 negative strip(s)

____unmounted page(s)
(notes, drawings, letters ...)

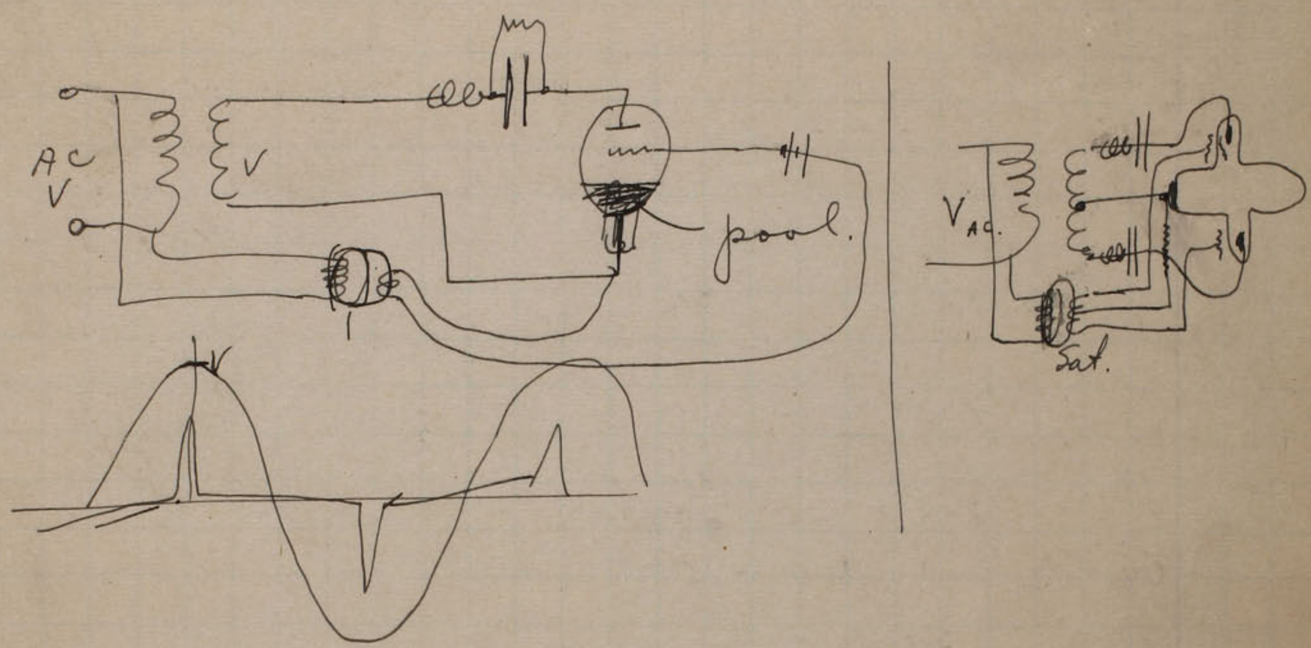
was/were scanned where originally located between page 54 and 55.

Item now housed in accompanying folder in MC 25, box 166

Oct 30, 1930

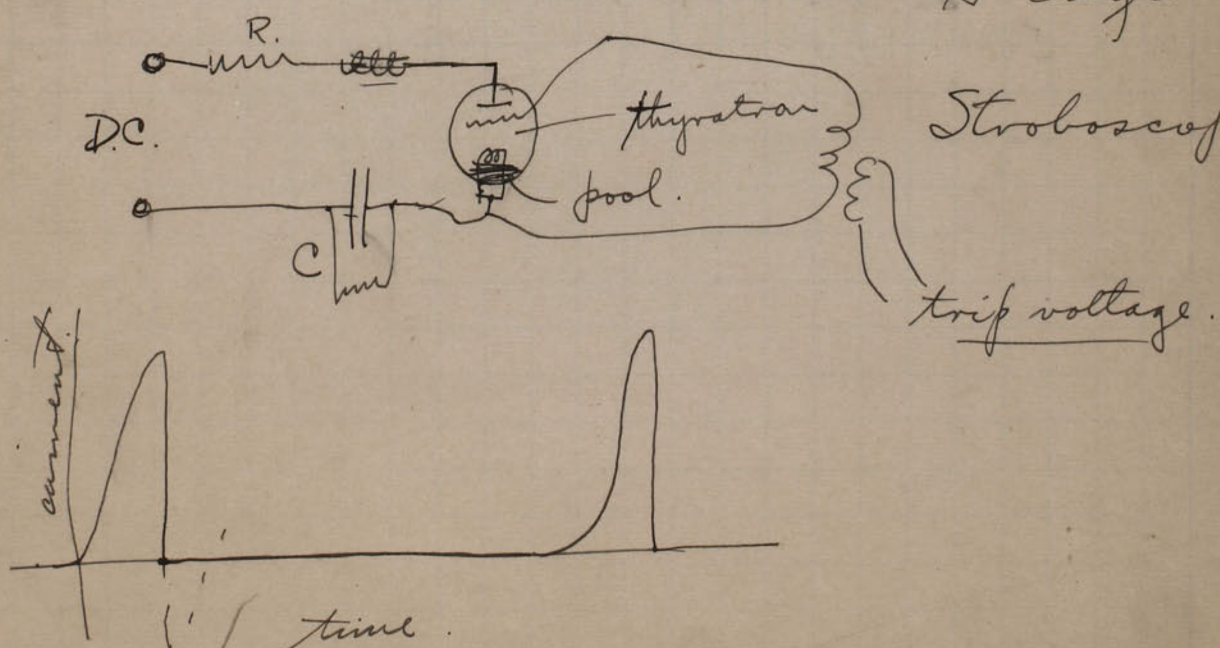
A.C Stroboscope

Oct. 25, 1929.
H. E. Edgerton



Oct. 25 1929
H Edgerton

Stroboscope



Oct 30 1930

GO-882 1m 4-27-29

Name H. E. EDGERTON Dept RESEARCH.
(Typewrite Name and Dept.)

Agreement

Place Schenectady N. Y. Date June 3 1929

In consideration of my employment with the General Electric Company from June 3 1929 to Aug 20 1929, I agree:

I will communicate to the Company's Patent Department all inventions made or conceived by me during my employment by the Company or within a period of one (1) year from the end of such employment which are along electrical lines or along lines of the Company's work and investigations, or of those of companies in which it may have a substantial interest, or resulting from or suggested by any work which I may do for the Company, or at its request, and will assist the Company and its nominees in every proper way (entirely at its or their expense) to obtain for its or their own benefit patents for these inventions in any and all countries, the inventions to be and remain the property of the Company or its nominees whether patented or not.

As a matter of record I have given below a complete list of all inventions, patented or unpatented, including a brief description thereof, which I made or conceived prior to my employment, and I desire that these inventions shall be excluded from this agreement.

WITNESS:

(Signed) Harold E. Edgerton
(Sign first name in full)

State of New York
County of Schenectady } ss.

On this 3rd day of June 1929 before me personally came Harold E. Edgerton to me personally known, and known to me to be the same individual described in, and who executed the foregoing agreement, who acknowledged to me that he executed the same, and for the purpose therein set forth.

Agnes J. Harding
Notary Public

RESERVED INVENTIONS AND BRIEF DESCRIPTIONS THEREOF

Stroboscope - a device, using an electrical circuit including ~~an~~ mercury arc lamp, for observing moving objects.

Speed-Control an electrical network for controling the speed of a d.c. motor

(Continue list on back of form)

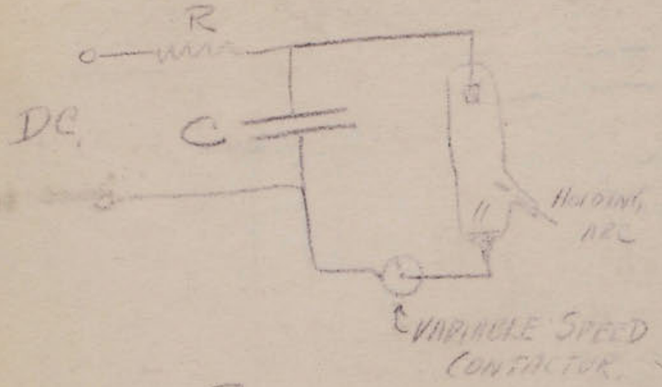
Original to be signed by employee, acknowledged before a Notary Public, and forwarded to the Patent Department at Schenectady. Copy to be given employee.

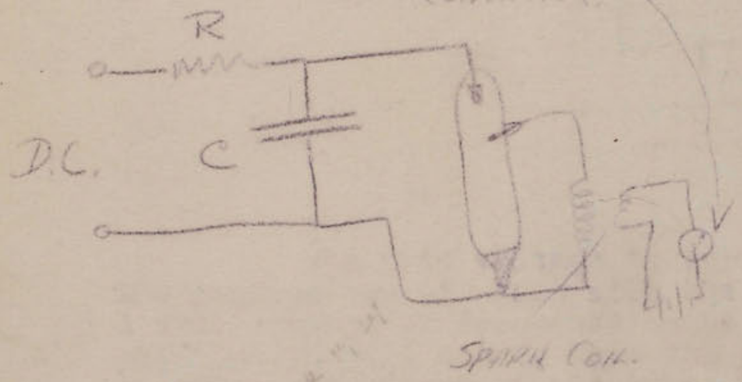
[SEE OVER]

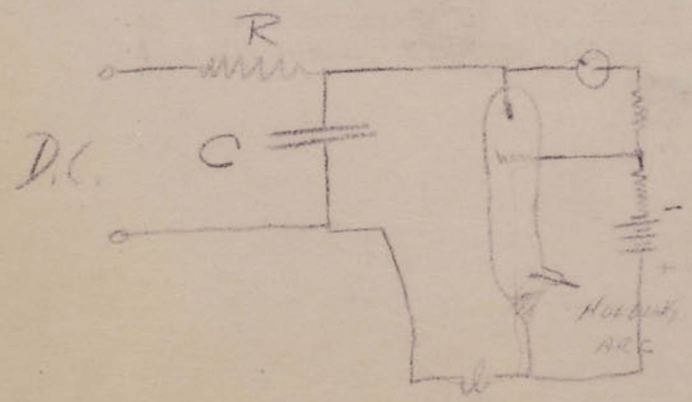
Oct 30 1920

RESERVED INVENTIONS AND BRIEF DESCRIPTIONS THEREOF (Continued)

STROBOSCOPE CIRCUITS.
USING IONIZED MERCURY
VAPOR TUBES.

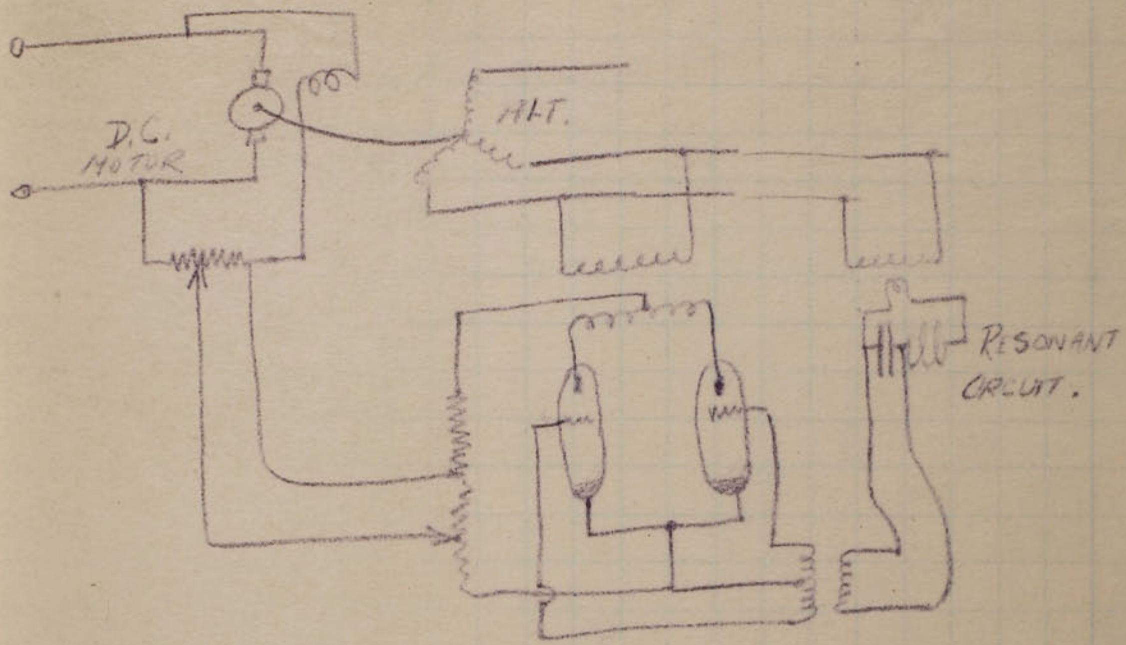






H. E. EDGERTON
JUNE 6 1929.

Circuit to hold constant frequency.

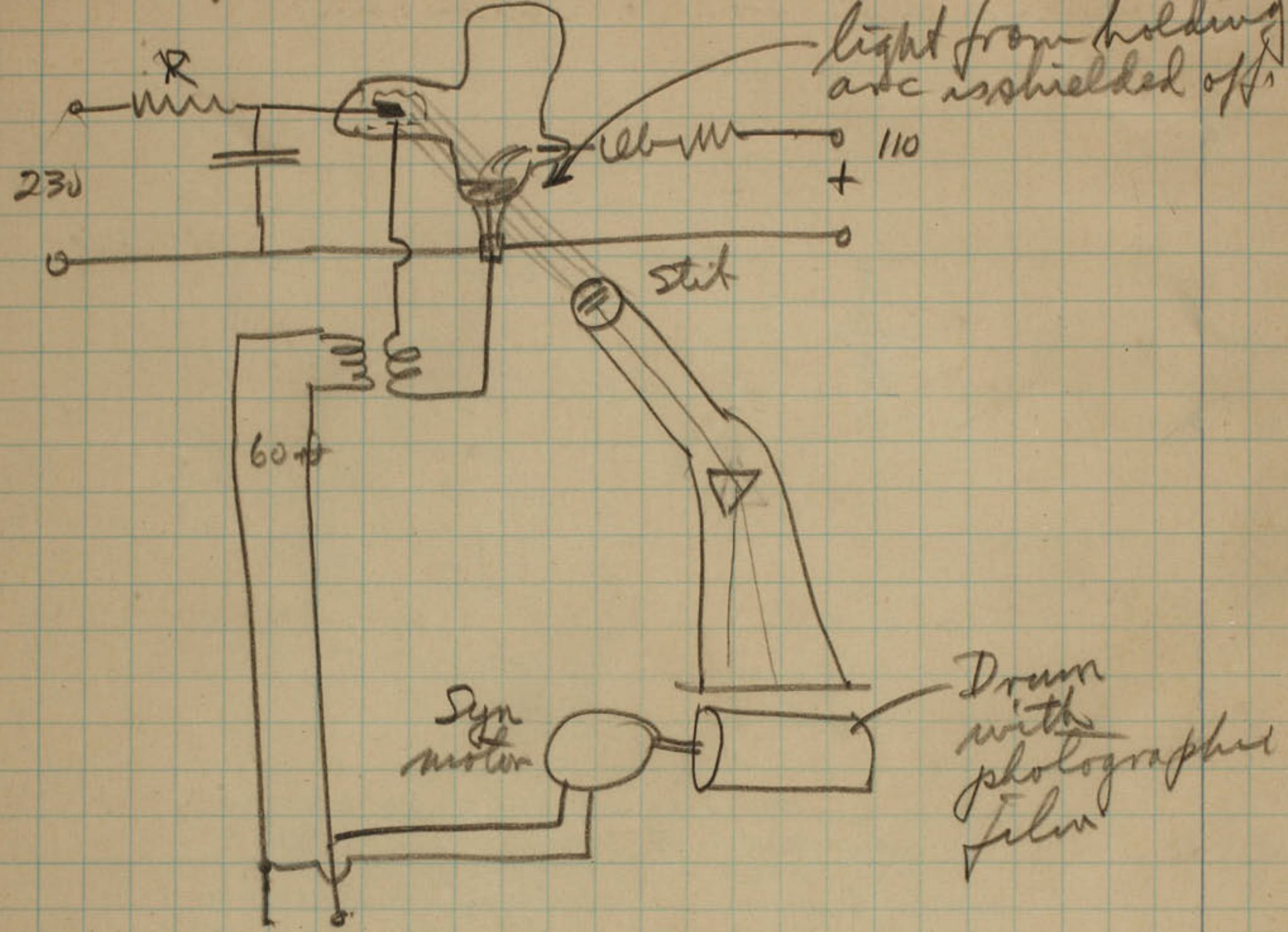


The grid voltage is approximately 180 degrees out of phase with the anode voltage. A small change of frequency means a large phase shift which will either turn the thyratrons on or off. The output of the tubes is connected so that it influences the field of the d.c. motor in the proper direction. A small change in the constants of the tuned circuit will move the frequency that is being regulated.

H. E. Edgerton
June 6, 1929.

Nov. 22, 1930
H. E. Edgerton

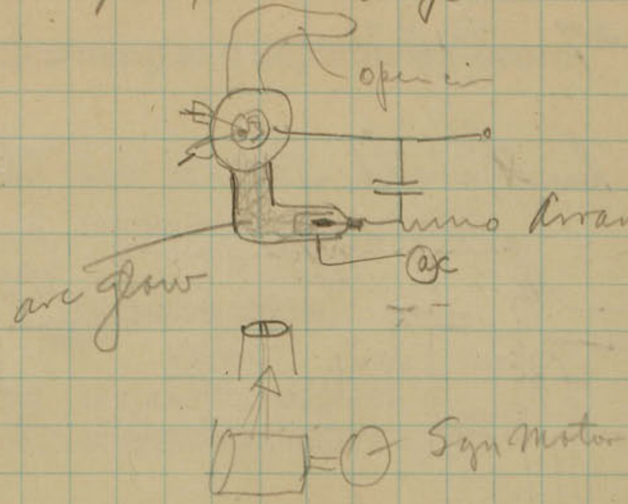
Spectrum Analysis of ~~Stroboscope~~ Output.
Stockbarger's Radiation Laboratory.



This picture looks interesting. Apparently there is a shift of wavelength which is about 6 angstrom for one wave length according to Stockbarger. Pres. Compton said it might be due to Doppler effect. The persistance of some of the lines give a clue to the deionization time.

Mon
Nov 24 1930
H. E. Edgerton

For the picture taken saturday the arrangement of the thyratron and the spectroscope was the following.

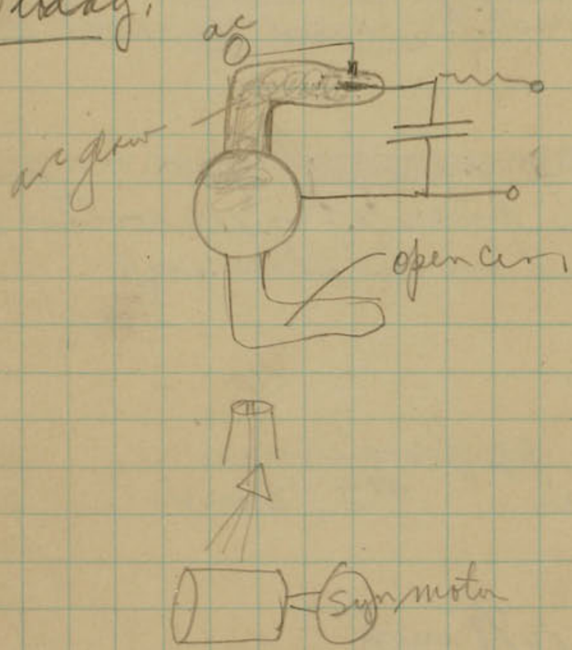


Arrangement for F29.

10 min exposure

Yesterday.

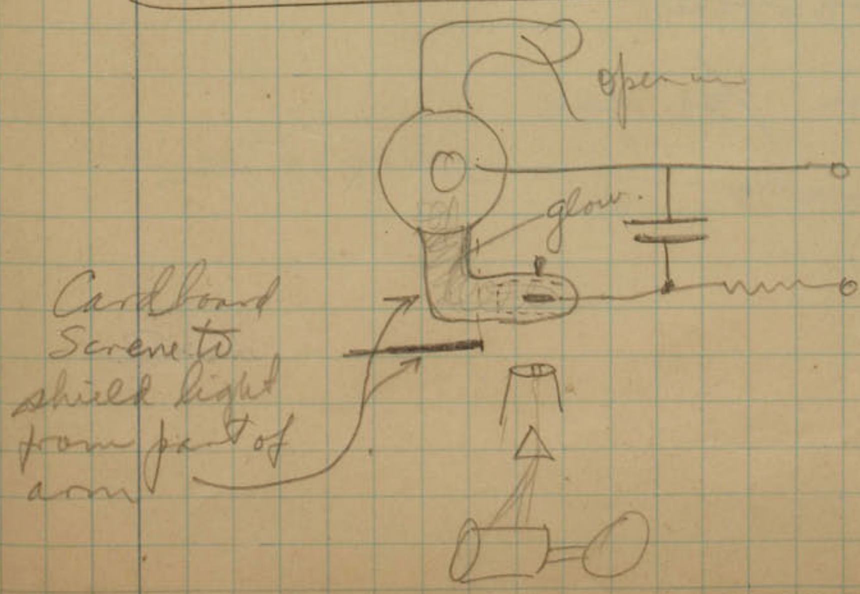
Arrangement for F30.



30 min exposure.

Arrangement for F 31.

10 min exposure.

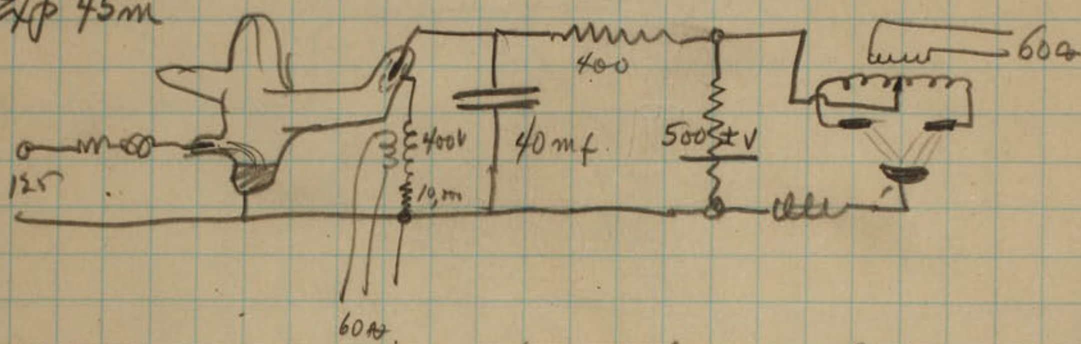


November 28, 1930
H.E. Edgerton. D.C.S. & L.B.

Radiation Laboratory 4-115 see B-32 notebook.

F32. The slit was reduced from 3mm to 1/2 mm.
Same as F 27. Exp 30 m.

11-29-30.
F33. Same circuit but with 500 v± on the condenser
Exp 45m



Full wave 500 volt rectifier used for cond. supply volt.

F34 Same circuit as for 33 except for
220 v on grid and a bias of −110 volts.
4 feet of lamp cord put in discharge circuit.
Exp 1 hr 19 min.

F35. Same as 34. Two exposures
90° apart #1 1 min #2. 5 min.

Circum of drum 10 1/8 inch
Speed = 1800 r.p.m.

10 1/8 inch for 1/30 sec

1 inch equalls $\frac{1}{30 \cdot 10\frac{1}{8}} = 3290 \times 10^{-6}$ sec.

Notebook Number: T-1

Scanning and Separation Record

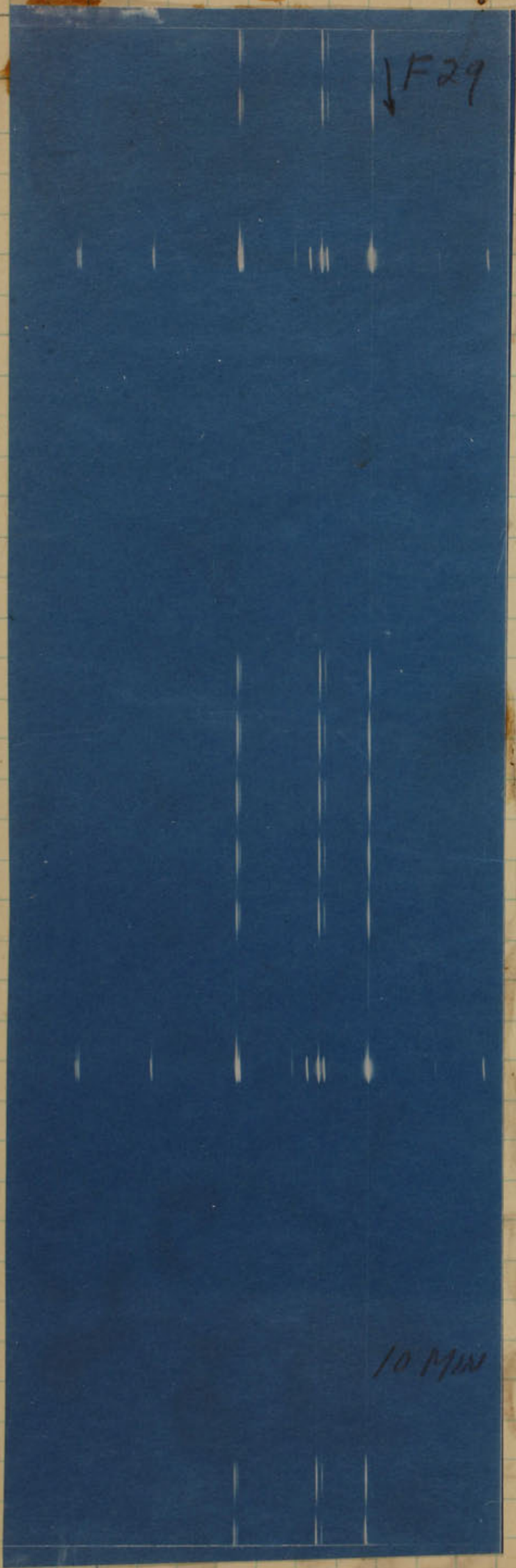
1 unmounted photograph(s)

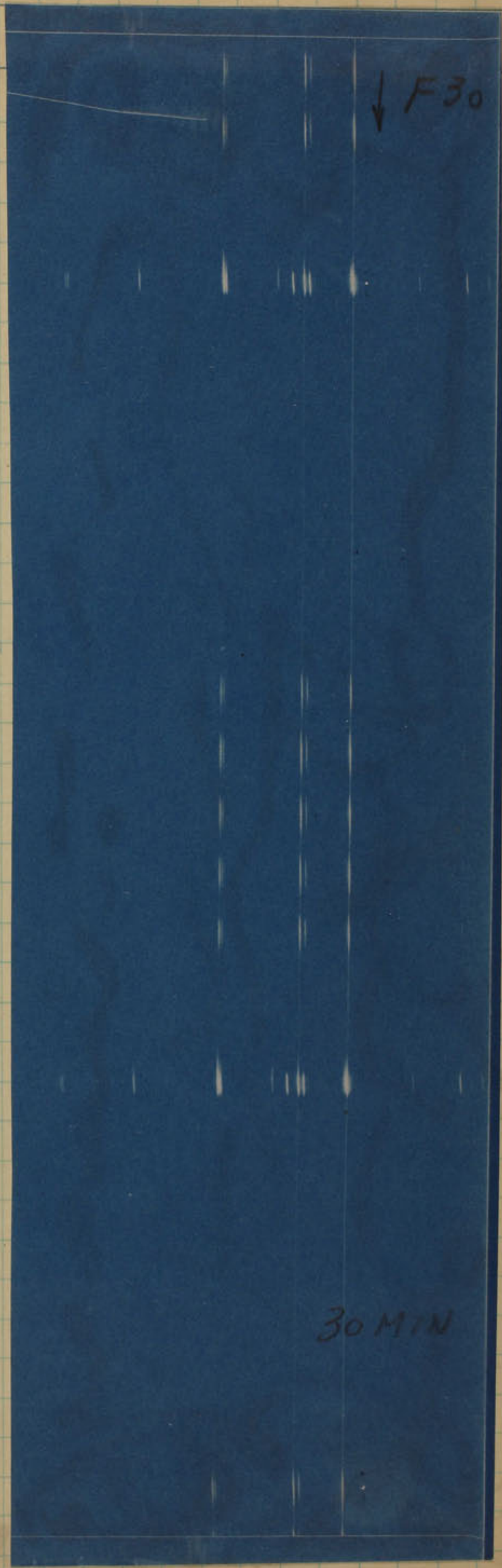
____negative strip(s)

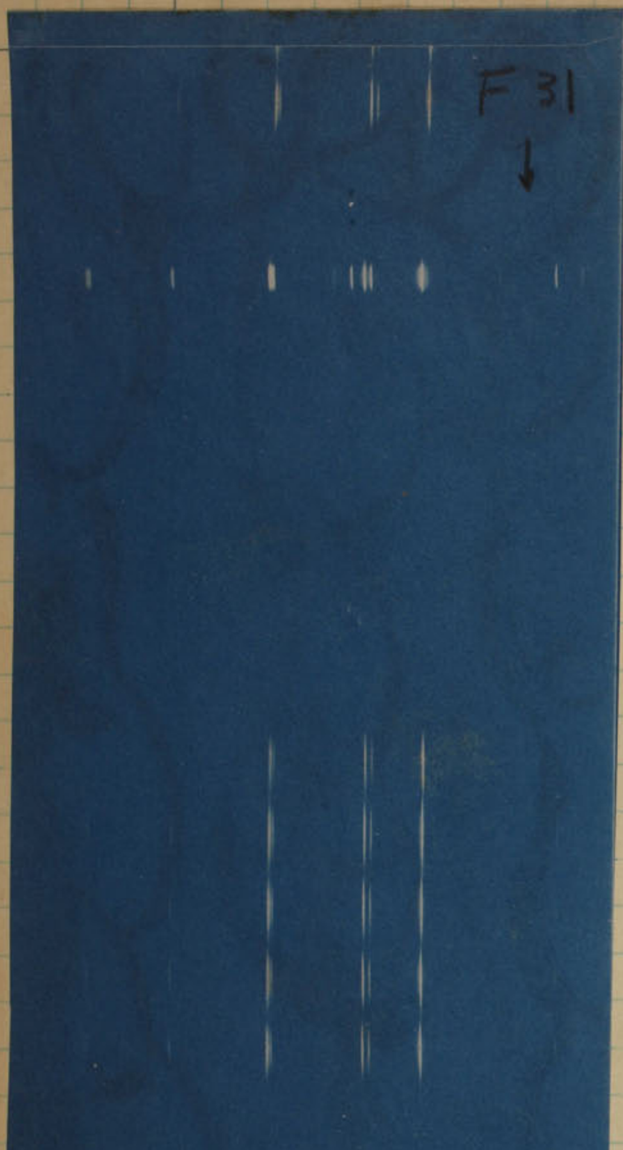
____unmounted page(s)
(notes, drawings, letters ...)

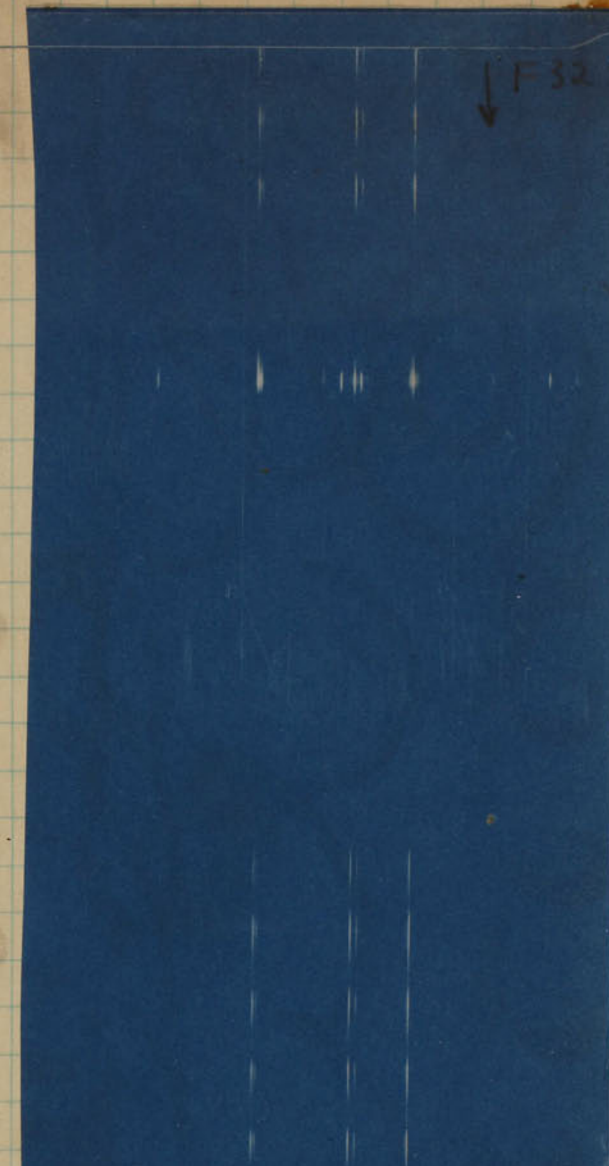
was/were scanned in place on page ~~where originally located between page~~
61 ~~and~~ ____.

Item now housed in accompanying folder in MC 25, box 166

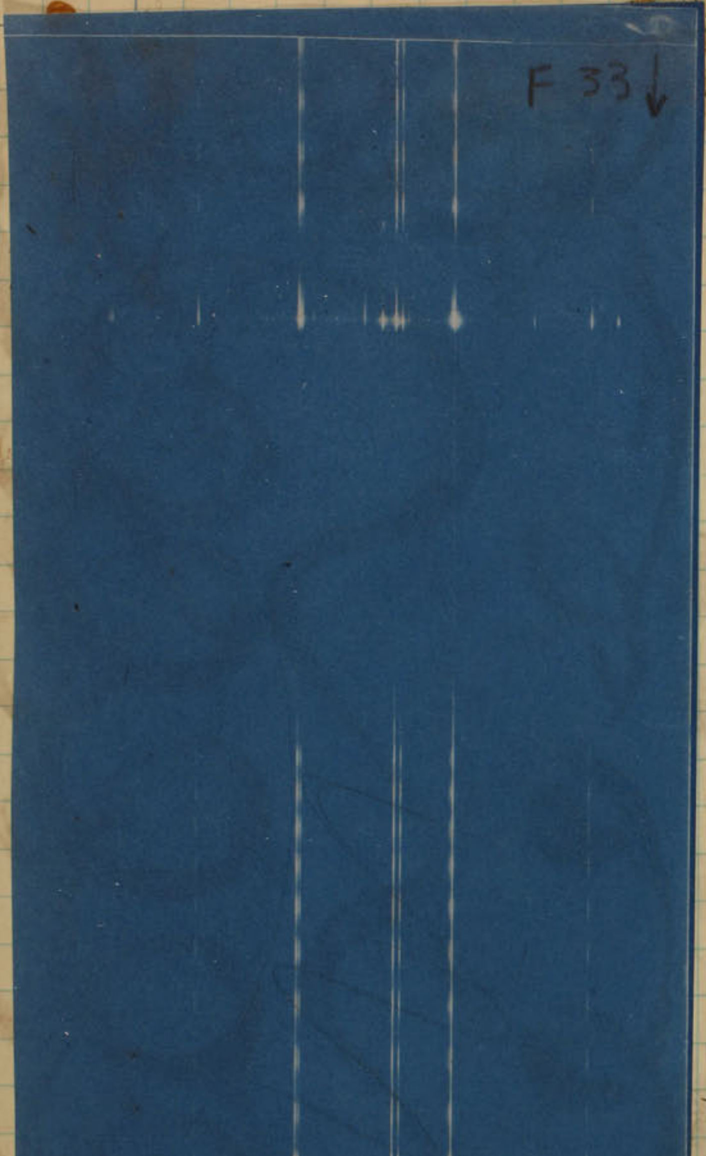

F29
10 MIN


F30
30 MIN

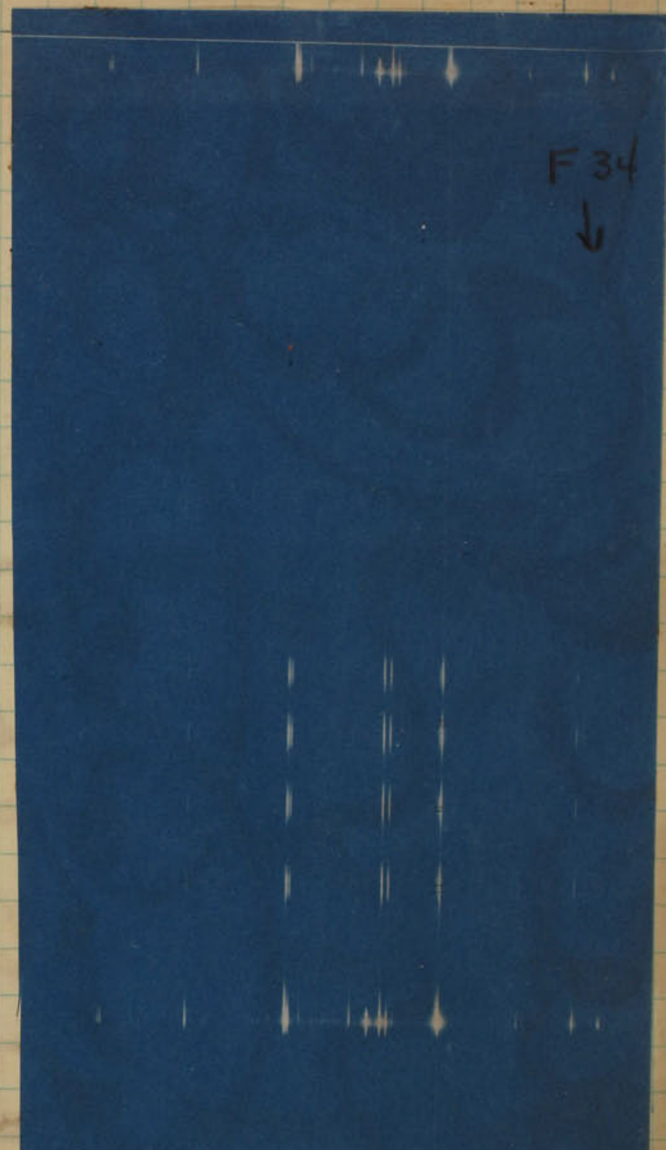

F 31
10 MIN


F 32
30 MIN

Grotrian: Graphical Spectra,

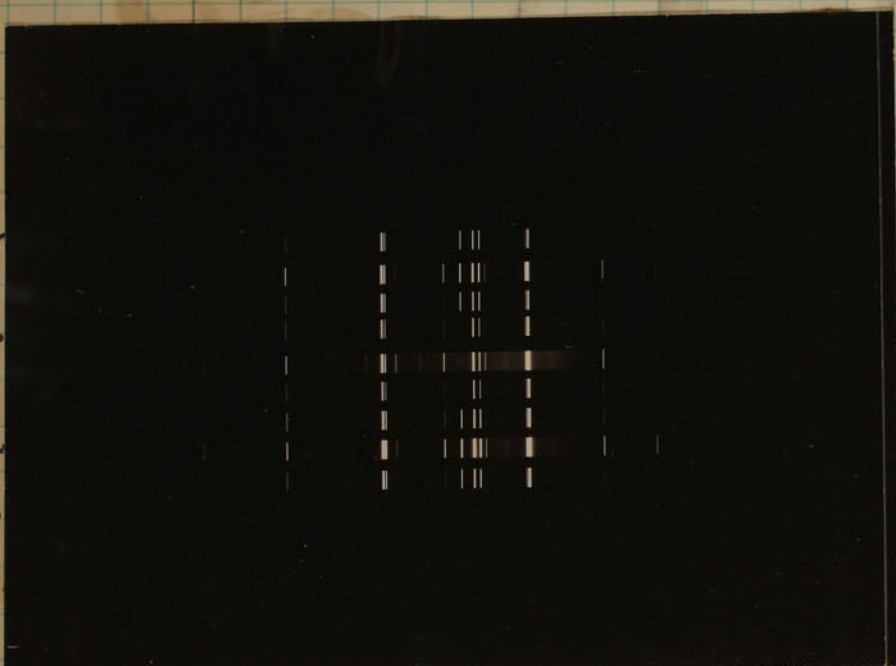


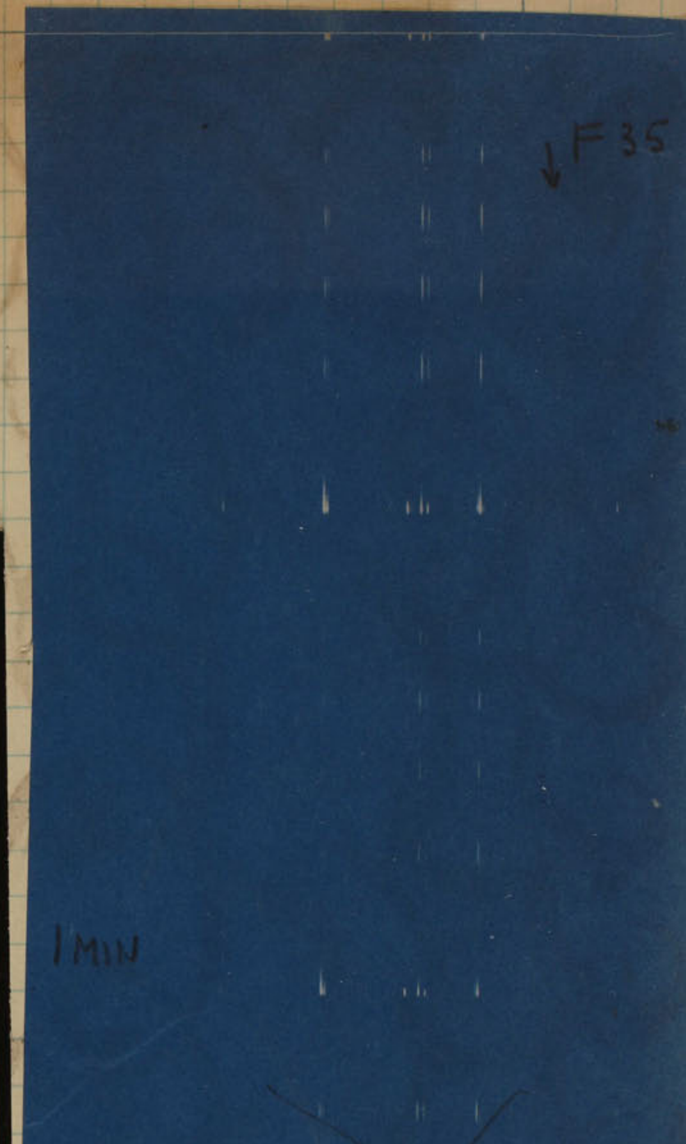
1" = 3290
M.S.



1 ANGSTROM = 10^{-8} CM.

S
C
S





S - Stroboscope

C - Ordinary arc 0.5 amperes ±.

Notebook Number: T-1

Scanning and Separation Record

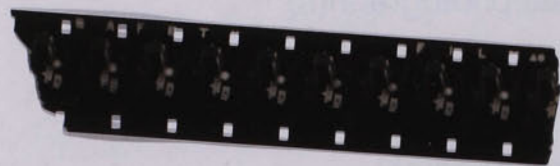
____unmounted photograph(s)

2 negative strip(s)

____unmounted page(s)
(notes, drawings, letters ...)

was/were scanned where originally located ~~between page~~ in envelope on page
65 ~~and ____~~.

Item now housed in accompanying folder in MC 25, box 166



Moving pictures taken
of Substation Generator
Dec 6 1930 by Henry Lane.
F 1.9 lens. Cinekodak. 16 frames per sec
Panchromatic film.

H. E. Edgerton
Chas Kingsley

Enlargement on page 85 of
some of these films. Still
photo on page 82.

Dec. 4, 1930
H. E. Edgerton

Prevention of Hunting.

Method of making the quadrature excitation a function of the slip so that the excitation will help to stop angular oscillations.

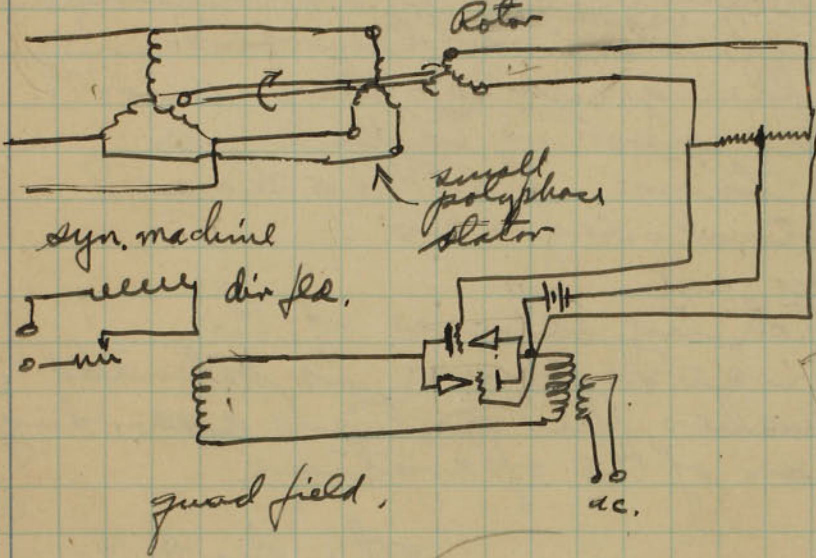
Synchronous machines are as a rule not sufficiently damped as a ~~x~~ consequence are subject to violent swinging at times of load changes.

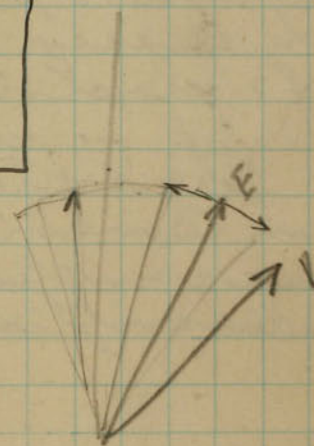
This circuit endeavors to apply an auxilliary excitation in the quadrature axis, which is a ~~frequency~~ function of slip. DC in the quadrature field shifts the axis of the combined excitation ~~voltage~~ or the combined field ampere turns. This shift of the field is the same as changing the angular displacement. Consider a motor just after a sudden load has been put on the shaft. The defficiency of torque causes an accelation and thus a slip. As the slip becomes appreciable an excitation is introduced into the quadrature field in such a direction that it shifts the resulting field axis towards its final value. This immediately reduces the acceleration and reduces the over swinging. If the rotor should swing too far the slip will be ~~the~~ opposite in sign and the excitation in the quad. field will reverse and thus shift the excitation axis back ~~again~~.

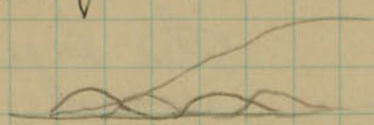
Method of obtaining voltage prop. to slip.

A small polyphase machine directly connected to the shaft is supplied by polyphase current from the large machine. The rotor of this small machine will have no voltage induced in it when the rotor is running synchronously. As soon as the speed departs from synchronism because of slip then there will be an induced voltage.

The induced rotor voltage allows current to flow in the quadrature field by means of a thyratron. Two thyratrons are used so that the direction of current can be controlled.





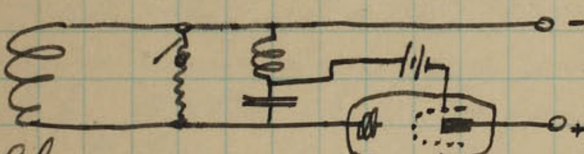


Dec. 15, 1930

Thyratron relay for switching the excitation to a synchronous motor at the most favorable angle.

An electrical device which can close the field switch of an synchronous motor at an angular displacement of about zero electrical degrees makes the pulling-into-step smooth and allows the motor to pull in much easier than if it is closed at 180 electrical degrees.

The switching scheme of the Brown Boveri company is patented and accomplishes this action according to this description of the operation.

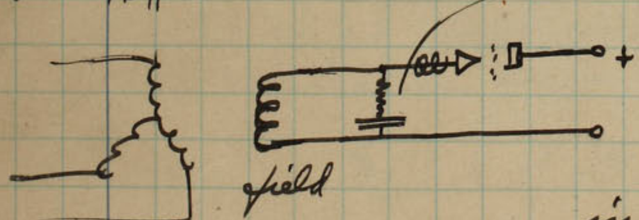


field

The excitation would not come on until the frequency of the induced current in the rotor was small.

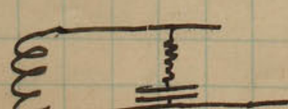
This circuit does not have enough good features.

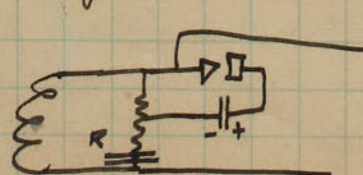
Dec 16 1930

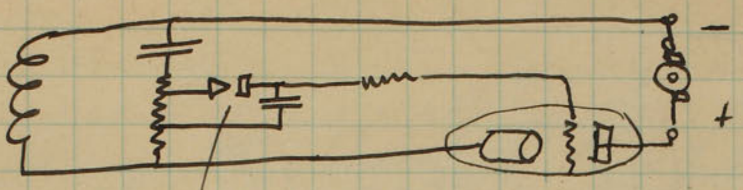


Field discharge in series with a condenser so that any ac can go through

I wonder what an induction motor will do if it has a rectifier in its rotor circuit? This will make a good experiment to try.



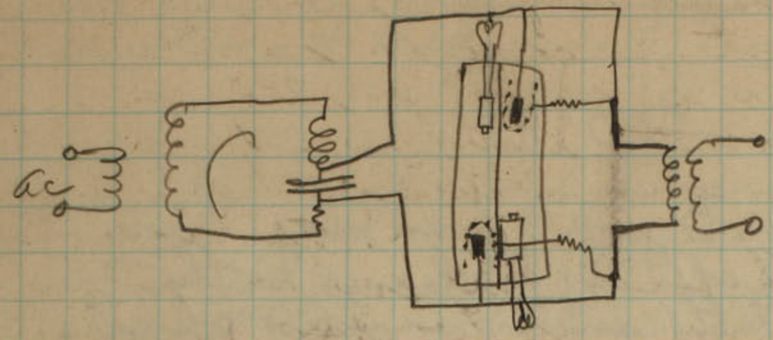




rectifier to give to grid neg. bias and thus to hold off the discharge in the thyratron until the motor is up to speed.

Dec 17 1930
H E Edgerton

A-C Thyratron Stroboscope Circuit



The condenser will build up a charge each half cycle and then discharge through one or the other of the two stroboscope tubes which are put in parallel but end for end.

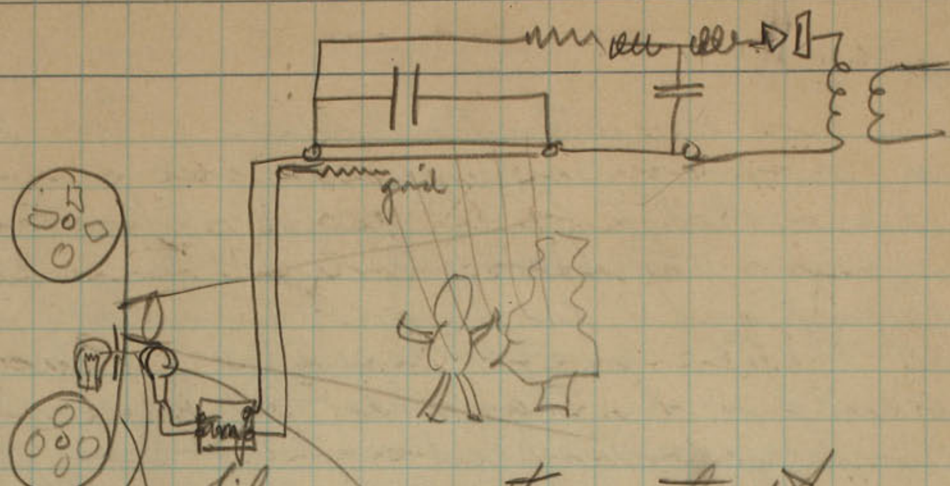
Dec 21 1930
H. E. Edgerton.

The intermittent speed of the film in moving picture cameras can be eliminated as well as the shutter by using stroboscopic light for illumination. Lansil and I discussed this last Friday at the P.E.E. problem section. The film would run through the camera at a continuous speed and the ~~lens~~ shutter would be open all the time. The stroboscopic light would be synchronized so to speak with the film so that an intense light flash would occur when the film was in the right position.

This scheme would certainly be ideal for fast movies since the main difficulty as I understand is the mechanical movement of the film. The time of exposure is about 10×10^{-6} seconds with the stroboscope circuit that I have now. I believe that this can be speeded up more if necessary.

Projection could also be made by reversing the process. A concentrated stroboscopic light would fall on the continuously moving film for so short a time that it would appear stationary.

Colored movies could be taken using two or more sources of light, for instance a red neon stroboscope and a blue mercury stroboscope. They would flash ~~on~~ so that alternate frames of the movie film would be exposed. The film would be panchromatic stock. Projection would require also two lamps one red and the other blue which would operate ~~alter~~ on alternate frames in the projector. The speed of projection would be 30 frames per sec or more so the eye could not detect the different colors.

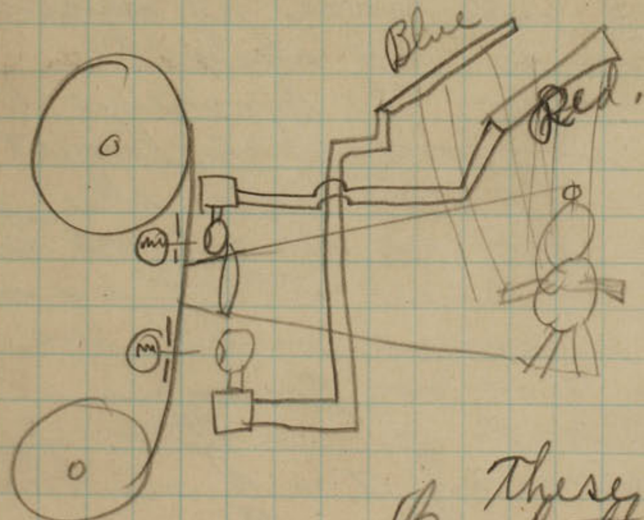


film runs at constant speed

no shutter

Photocell to flash light on object in synchronism with the frames of the film.

Double Color movies.



These photocells flash the lamps in synchronism with the frames. One cell flashes the red light every other frame and the alternate frames are flashed with the blue light on the object.

Jan. 17, 1931
H. E. Edgerton

Prof. Bowles helped take some more movies of the 160 hp motor in the dynamo laboratory on Thursday Jan. 15, 1931

These were taken on Panchromatic film at f 1.5 and at a film speed of 32 frames per second.

A telechron clock (1 r.ps) was photographed at the same time as the motor.

600-volts (or less) were used for the condenser.

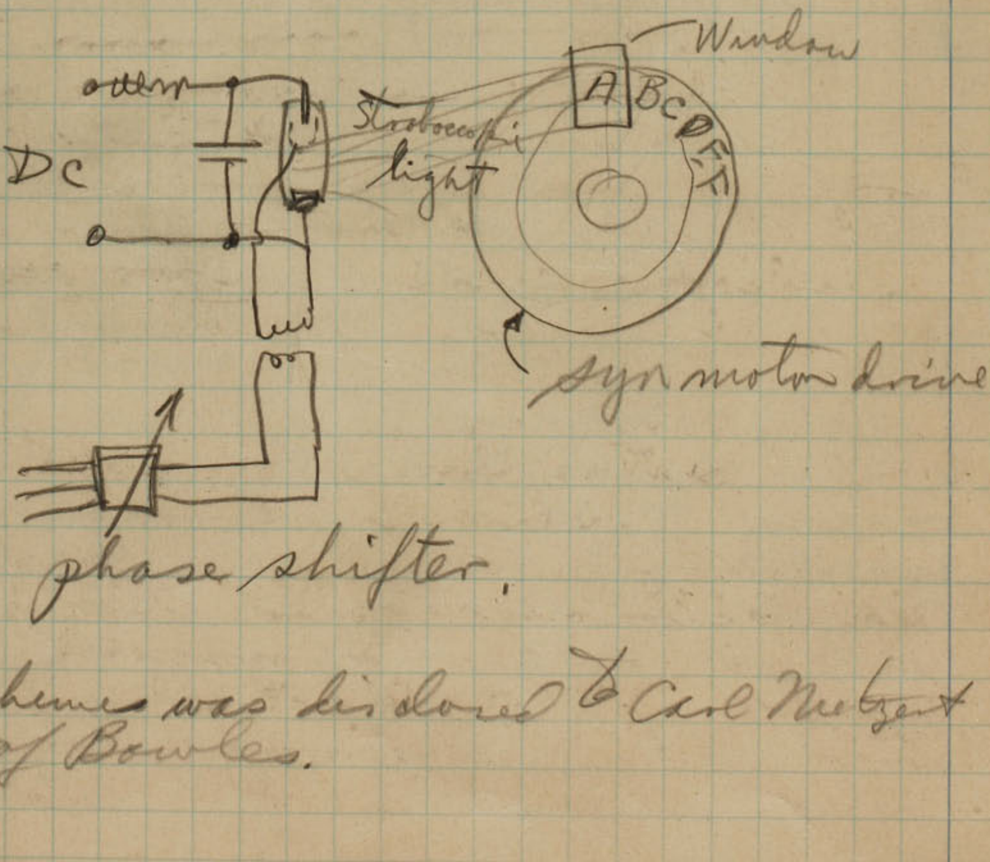
Switching transients showing the pulling into step transients were taken. These were for a load of
kw on the 25 cycle machine.

The field current was 10. amps (±).

Jan 19, 1931

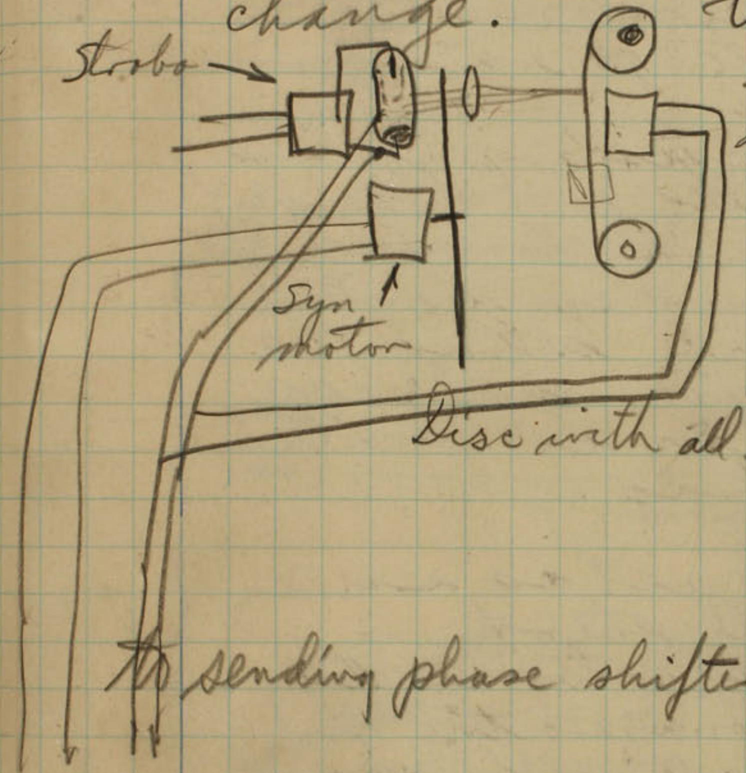
For the Popular Science lectures Prof Bowles used my stroboscope to show that communication could be sent by sending different ~~currents~~ frequencies down a line and having them light a tube which would stroboscopically ~~stop~~ stop a letter on a rotating disc.

Another way to do this would be to transmitt phase. A disc could be covered by a screen and left open at ~~only~~ only one place. A series of letters driven by a synchronous motor would show one letter through this hole depending upon the phase of the current sent down the line.



this scheme was disclosed to Carl Metzger and Prof Bowles.

The letters might be holes in the disc and the light focused on a piece of Bromide Paper. The paper would move intermittantly at the same time the phase would change. this could be done electrically quite easilly with a relay device



The message would come out in a strip and could be glued to the ordinary telegraph sheet.

During our experiments last week end we noticed that the light from the new tube that Dr Hull and Mr Found furnished us gave decidedly different colors during the main flash and the trailing ghost discharges.

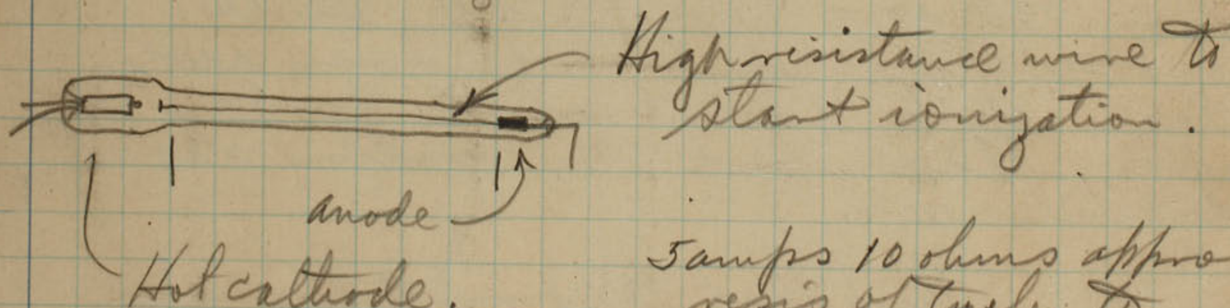
I think that this might make a way in which to change the quality of light from a mercury-arc lamp. An electrical circuit that makes a fast violent transient would accelerate different colors from the tube. Other gases ~~might~~ would help in getting the other colors also.

Jan 17 1930. Method of starting a
H. E. Edgerton mercury arc lamp (hot cathode).

One of the main difficulties of a mercury arc, hot-cathode lamp is the difficulty of getting it started. Usually a high voltage is required.

Now if a high resistance wire is ~~to~~ put in the tube and brought down ~~to the anode it~~ towards the cathode from and connected to the anode, it will extend the electrostatic field of the anode so that it can start an arc with a rather small voltage.

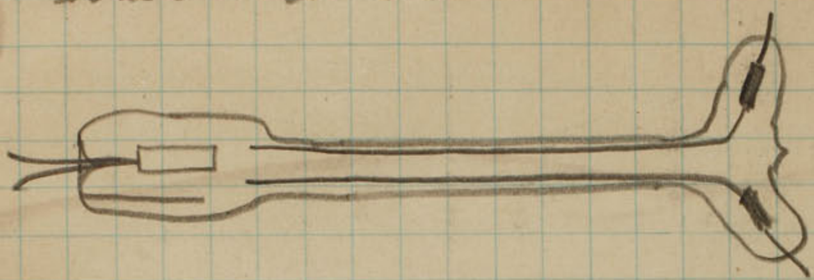
This will ~~will~~ act as an "accelerator" and will start ionization near the cathode. As the gas in the tube ionizes the main arc current will short the starting wire and it will not operate. The wire might be called a "preionizer" since it starts the ionization.



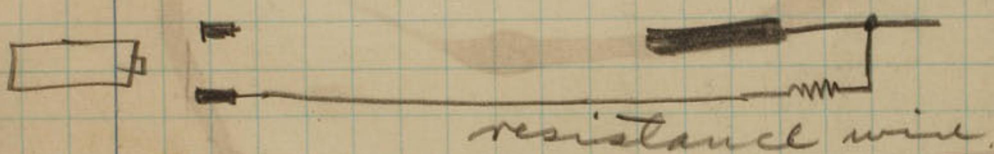
5 amps 10 ohms approx. resis of tube to 5 amps.

The resis. should be about 50 to 200 ohms or more.

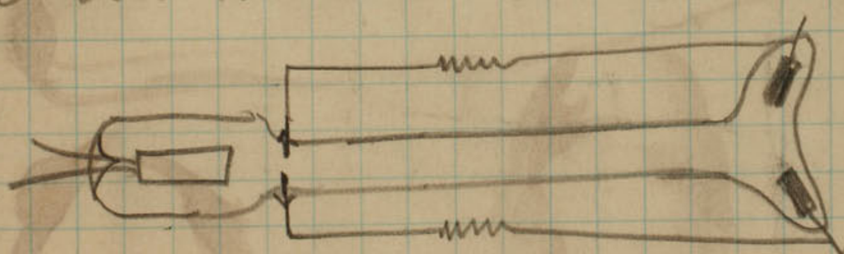
With a ac arc one wire would be put on each anode.



It would be better to connect the wires to the back of the anodes



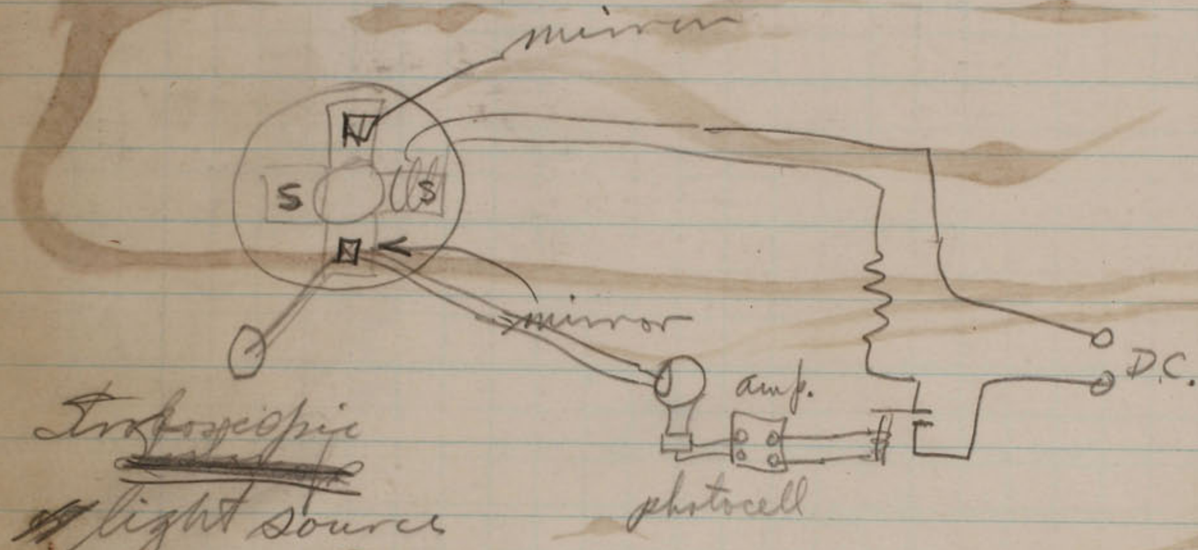
Another way would be to put ~~the~~ a small anode near the cathode and connect it with a high resistance to the main anode or two of them to the main anodes.



Glued Jan. 28, 1931.
H E Edgerton.

Jan. 27, 1931.
H E Edgerton.

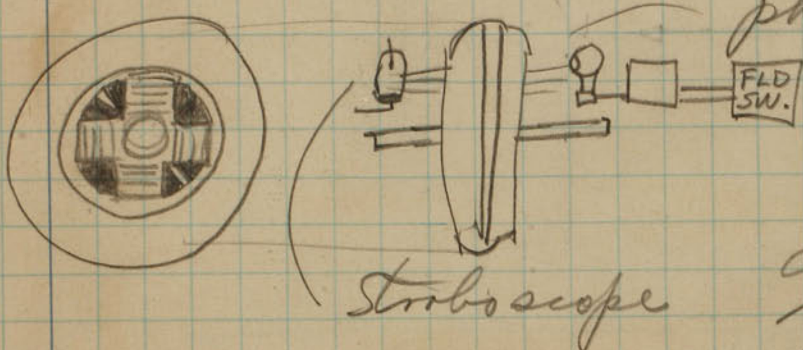
A method of synchronizing a ~~the~~ salient pole synchronous motor by switching the field current at a favorable angle.



A light beam from ~~the~~ a light would be reflected by a mirror on ~~the~~ a pole and so adjusted so that it would strike a light sensitive devise at a favorable angle.

Feb 3 1931.

Another way to switch the synchronous machine at the correct angle would be to allow the stroboscopic light to pass between the poles and then fall on the photocell.



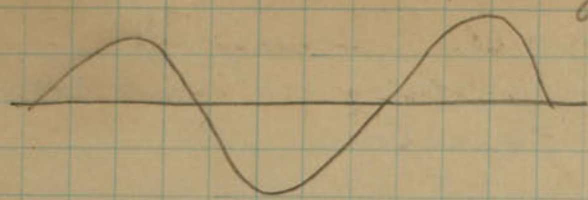
A partition of cardboard or metal would be put between the poles and would allow light to only pass when the angle was favorable.

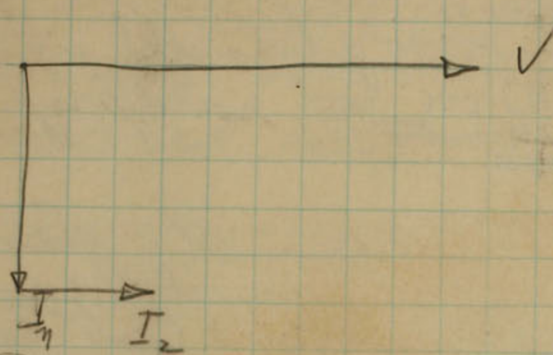
I remember having had this explained to me at about the date of above. I was then living with H.E. Edgerton.

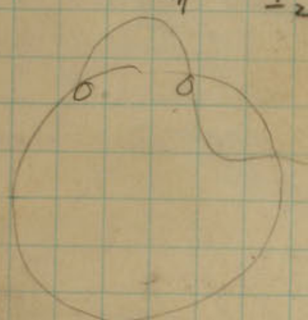
T. S. Gray
Nov. 7, 1935

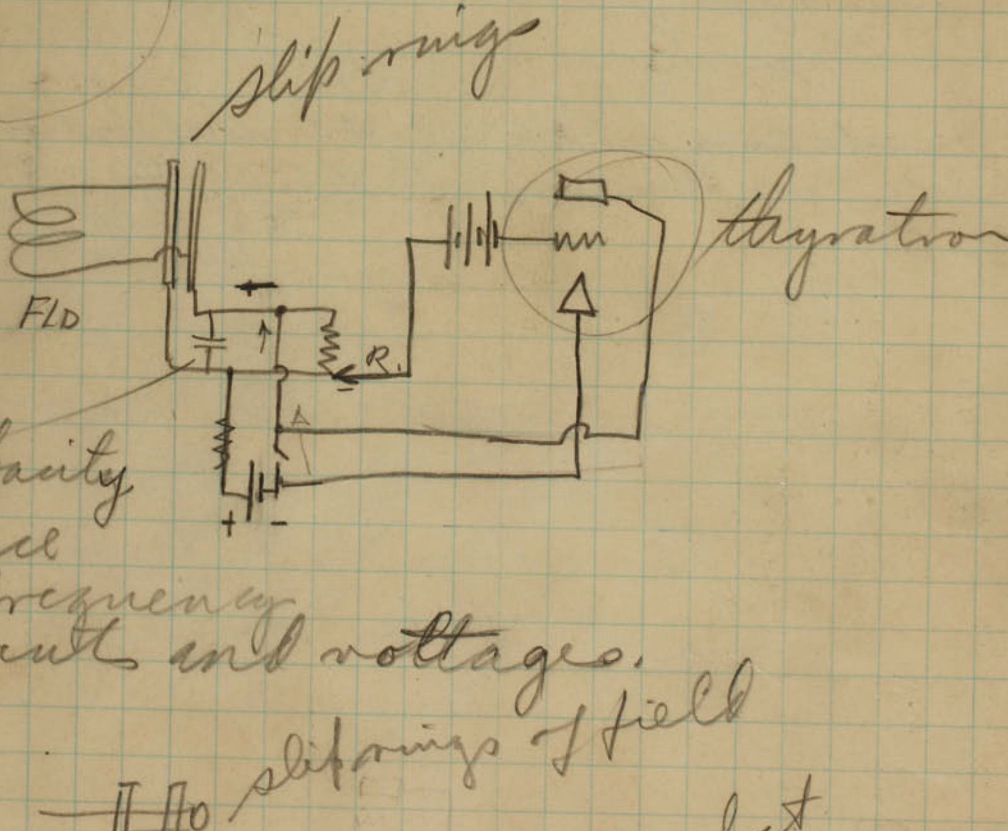
Feb 3 1931.

cont Method of exciting field of Syn Motor at a favorable angle.

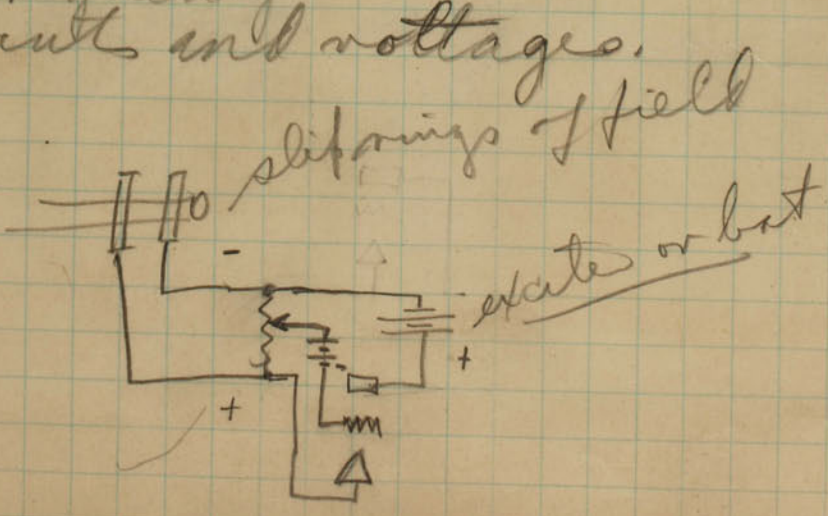






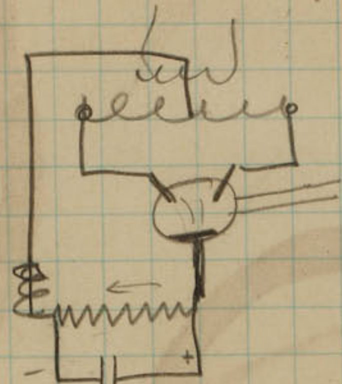


To reduce high frequency currents and voltages.

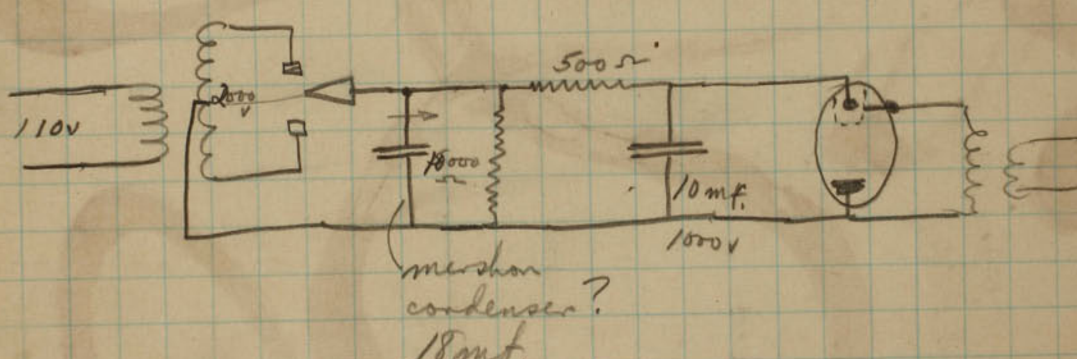


Feb 5 1931 H. E. Edgerton

Stroboscope circuits using the holding arc for a rectifier.

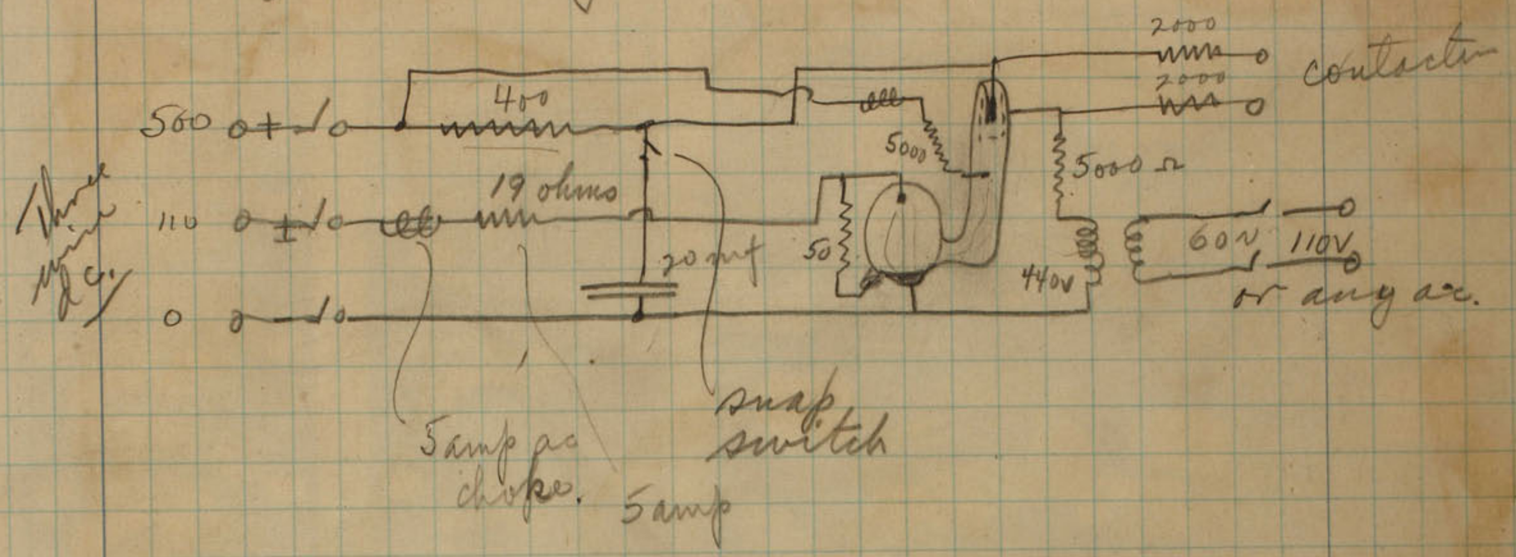


The polarity comes up wrong.

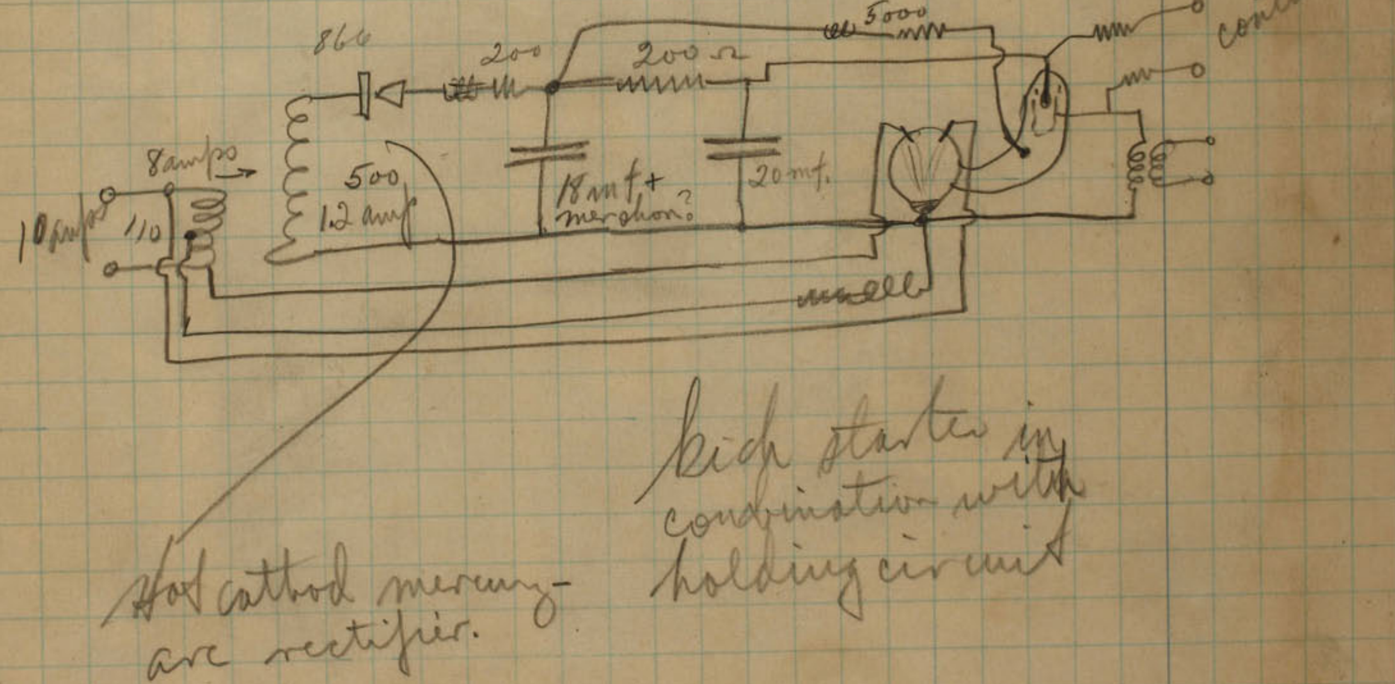


Stroboscopic photograph taken by Conant, of M.I.T. Photo Service.

Circuit for M.I.T. Dyn Laboratory Stroboscope Feb 6. 1931



All a-c model

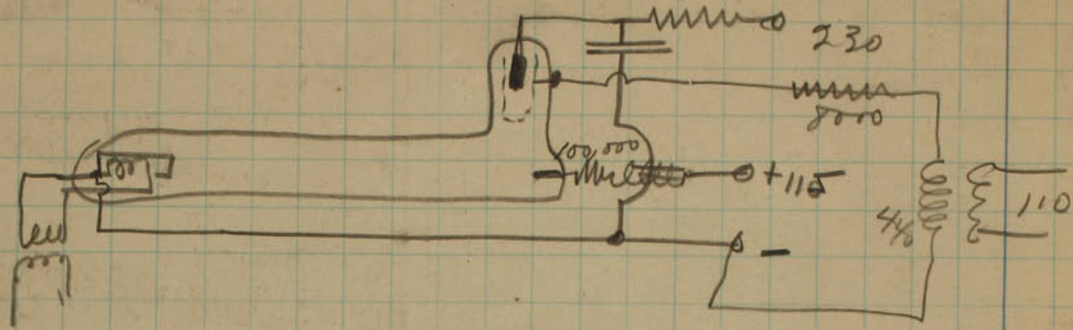


kick starter in combination with holding circuit

Hot cathod mercury-arc rectifier.

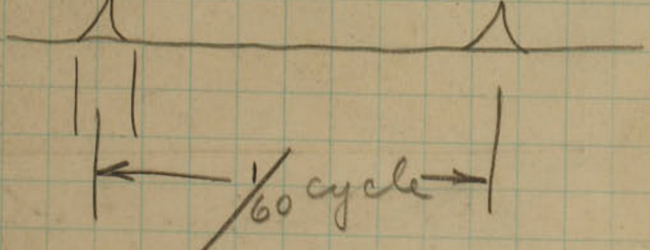
Feb 7 1931
H E Edgerton

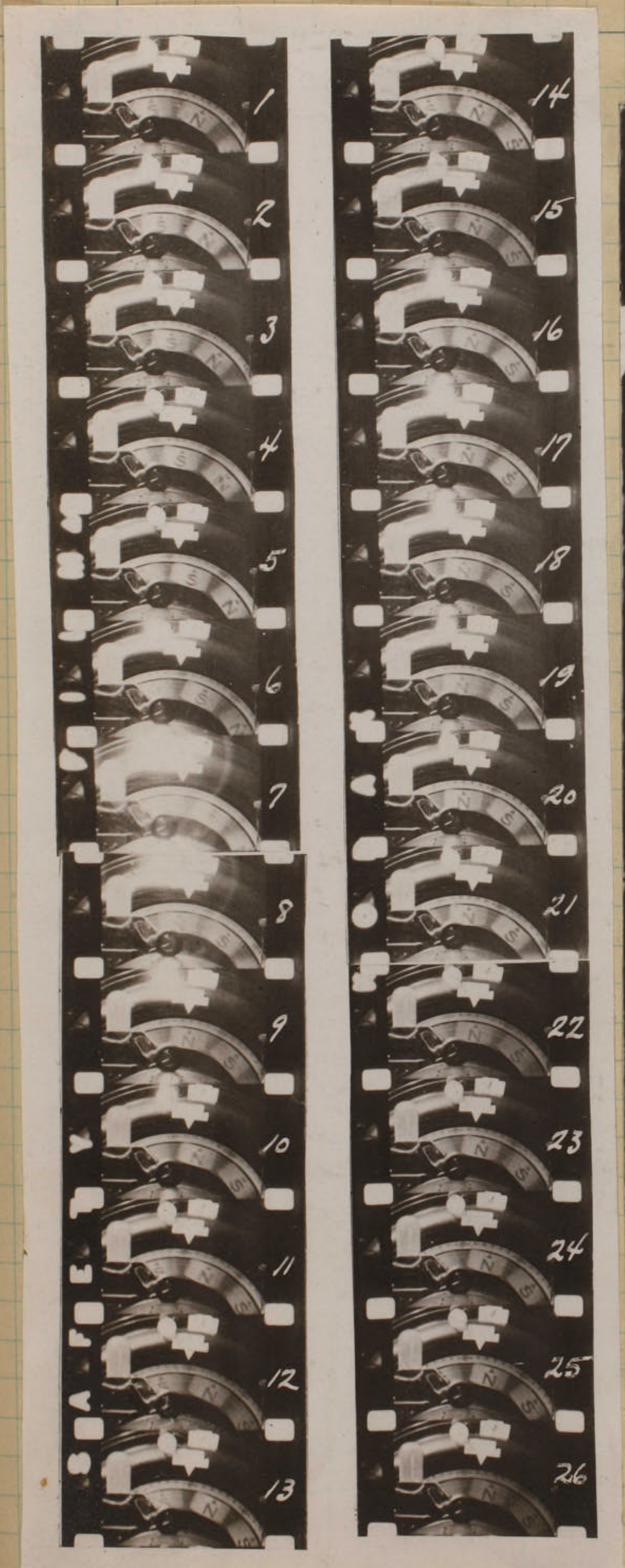
Stroboscope tests with hot cathode thyratron from Dr. A.W. Hull and C.A. Found.

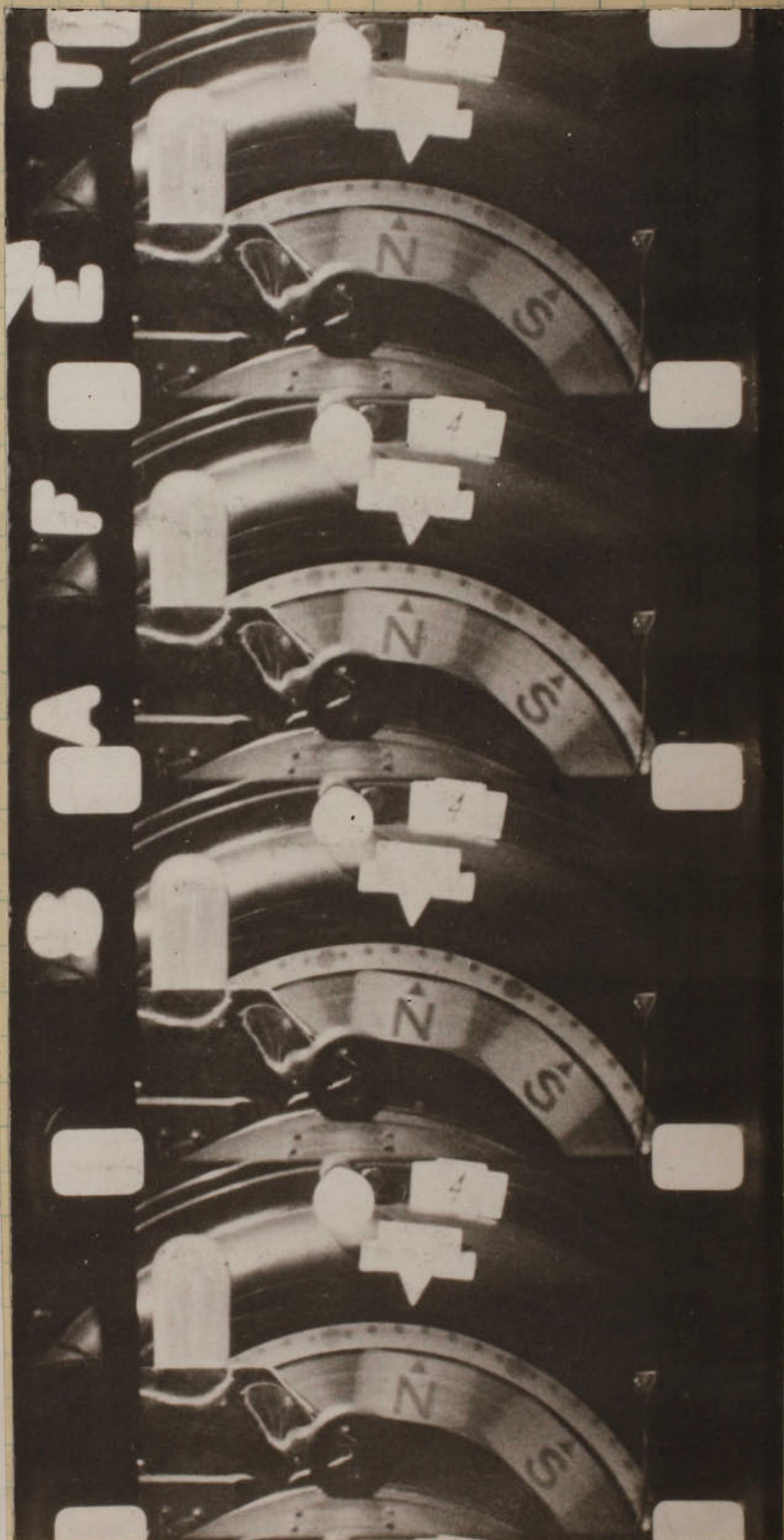


This tube does not seem to work as well as the pool type. The images seem blurred when ~~the~~ attemps are made to push up the light intensity. Oscillation occur with no volts on the grid. Factors influencing the frequency are the condenser capacity the charging resistance, the grid resistance and reactance. The reactance of the ~~grid~~ anode circuit ~~apparently~~ undoubtedly will influence the freq also.

Oscillographic observation of the plate or anode current when the violent ~~oscillations~~ discharges were made was as shown below. This illumination was unsatisfactory for most strobo purposes.







↑ 8x enlargement of 16mm film that was showed in New York at the AIEE Convention on Jan 30 1931.

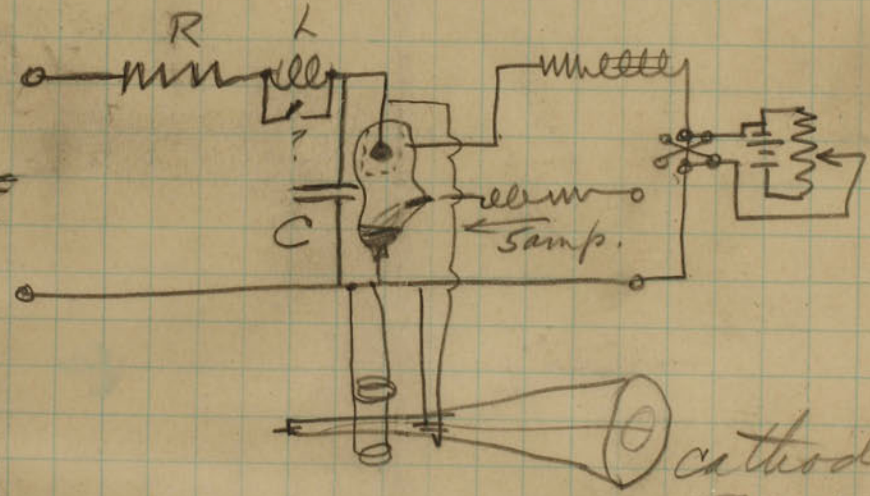
Feb. 10, 1931.
H. E. Edgerton

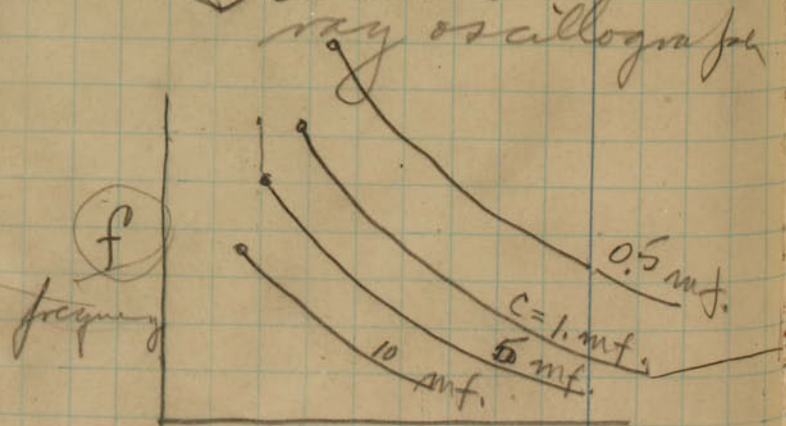
Dynamic volt-ampere characteristic of oscillations of mercury arc tube with condenser.

Factors influencing phenomena.

E - dc supply voltage.
R - changing resistance
C - capacity across tube.
~~R_G - res in grid circuit~~
temperature of tube.
L_1 in chg circuit (inductance)
L_G in grid circuit "

Other factors might be R and L in the discharge circuit





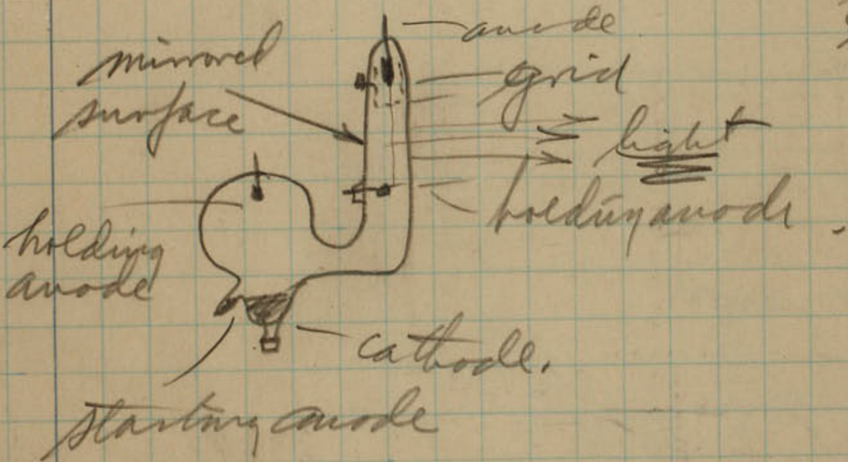
Expected results

The light from these oscillations are shown on pages 62 and 63, 61, 64.

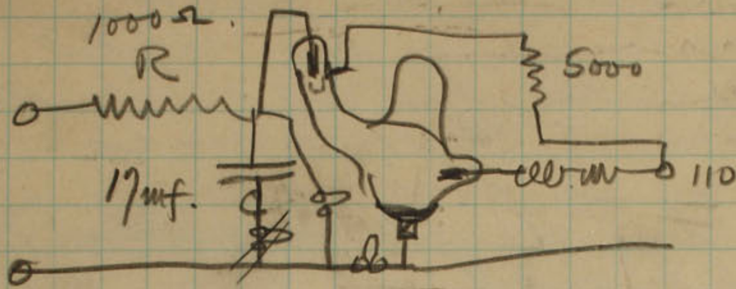
Feb 10 1930

I had a talk with Tom Killian today. He wants to use my stroboscope ~~[illegible]~~ for the aluminum banquet of M.I.T. The Physics glass blower is going to make the tube and ~~[illegible]~~ they will exhaust it too. Two of them will be made, one spare.

Killian suggested that the tube might be mirrored; this will be great, I think. The tubes we are going to make are like this. The mirrored surface will be connected to the grid and will help make over the tube.

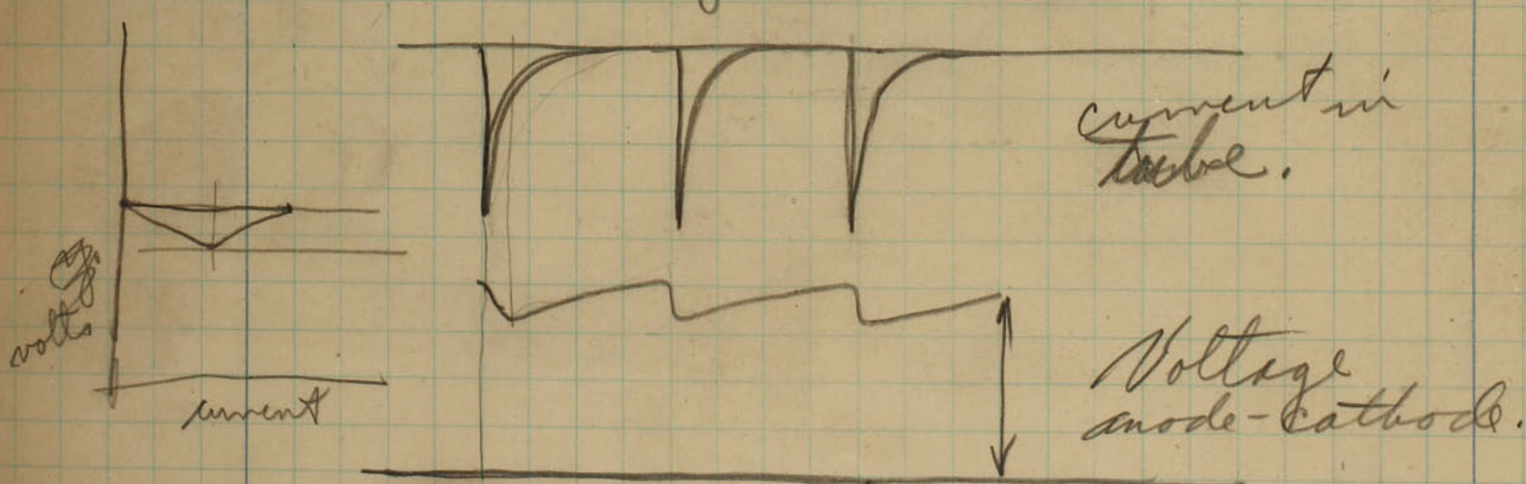


Feb 11 1930

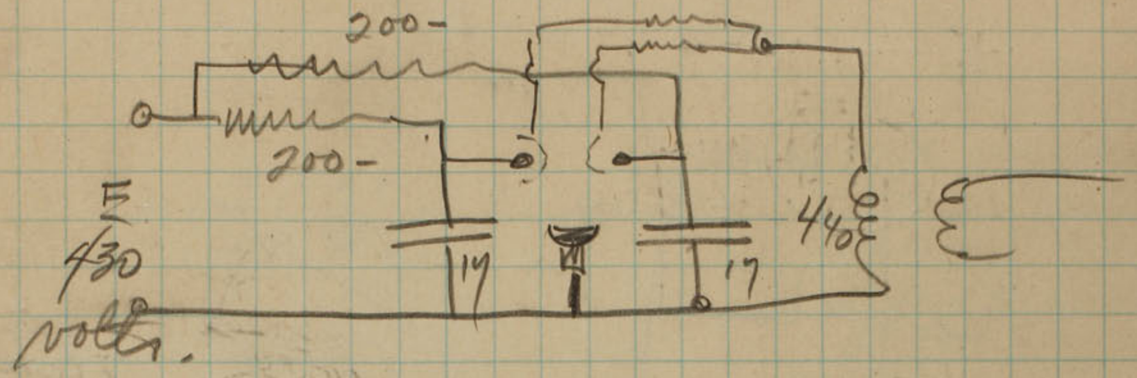


		V	R	C	Liaf settings on osc. volts,	amps.
	Osc. No 1.	230	1000	17mf.	1.5	.075
fast	2	230	"	"	"	"
"	3	430	"	"	"	"
slow speed	4	430	"	"	"	"
fast	5	"	"	"	"	"
slow	6	330	"	"	"	"

Appearance of oscillograms



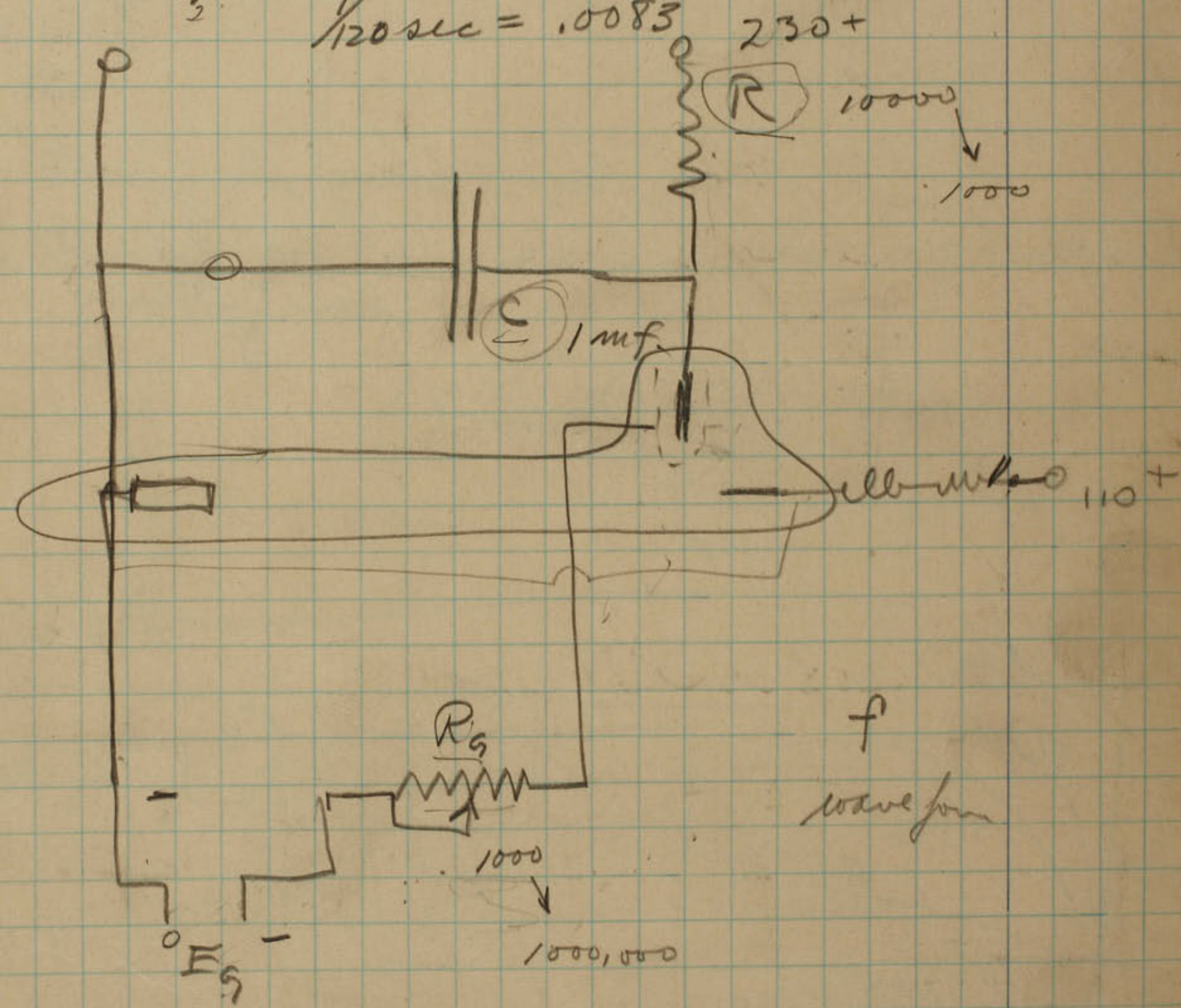
The frequency increases with the dc voltage and ~~the~~ the decrease of charging resistance.



$$RC = 200 \times 17 \times 10^{-6} = 3400 \times 10^{-6} = .0034 \text{ sec.}$$

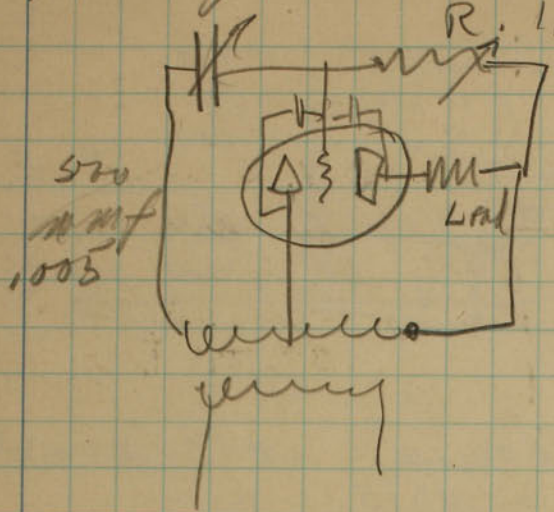
$$1/120 \text{ sec} = .0083$$

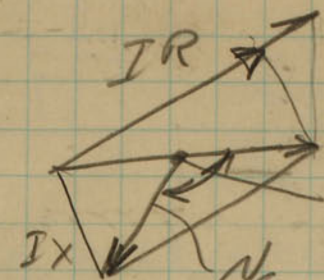
$120 \overline{)1.00}$ .100



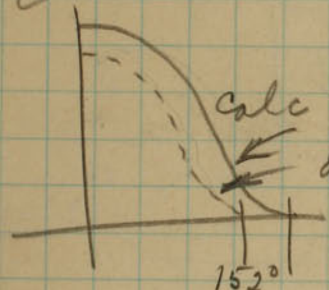
Nottingham's lecture Feb. 11, 1931.

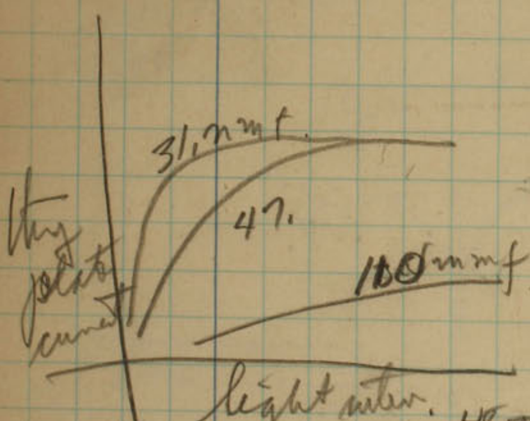
Phase shifter

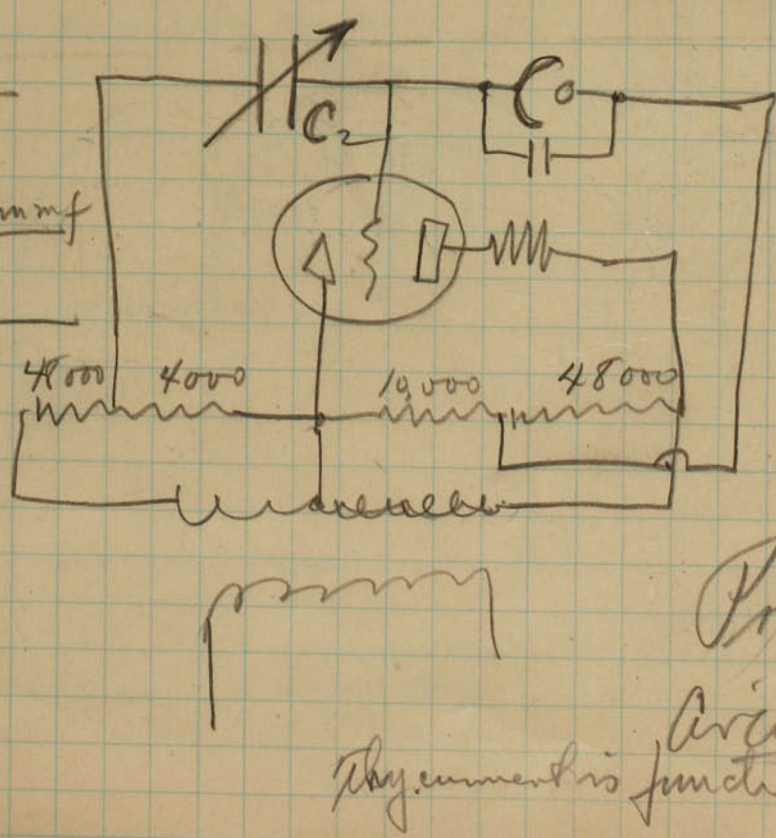




$\frac{1}{1000}$ sec time lag in volt-angle curve. Due to buildup of ionization.



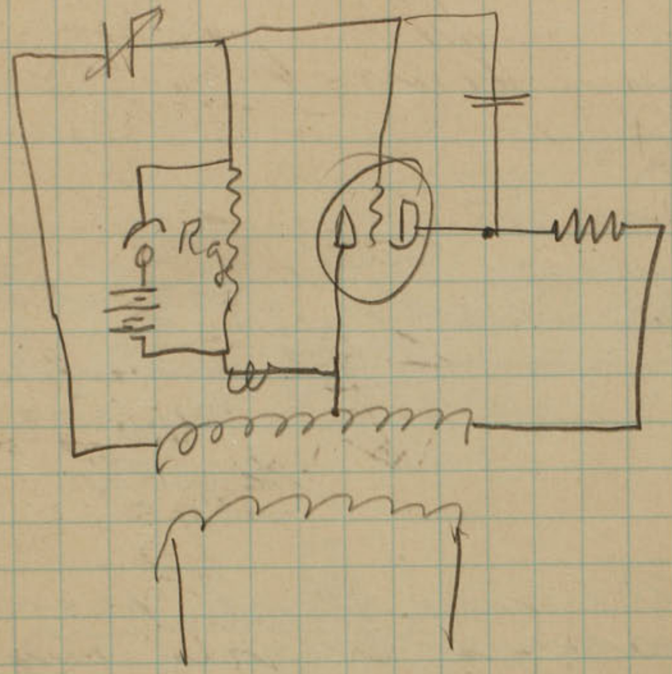




Proportional

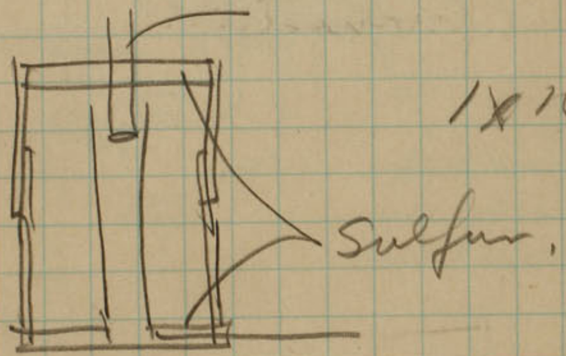
Circuit.

Thy. current is function of light.



10×10^{-9} current in amperes gives on and off control of the thyratron.

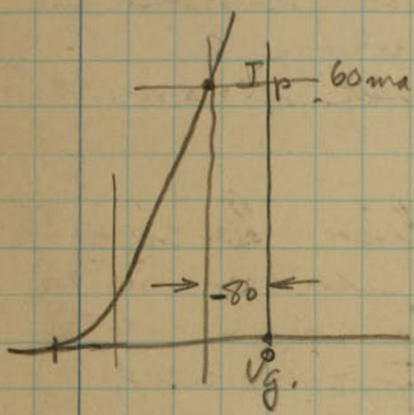
Condensers set in sulfur for low leakage.

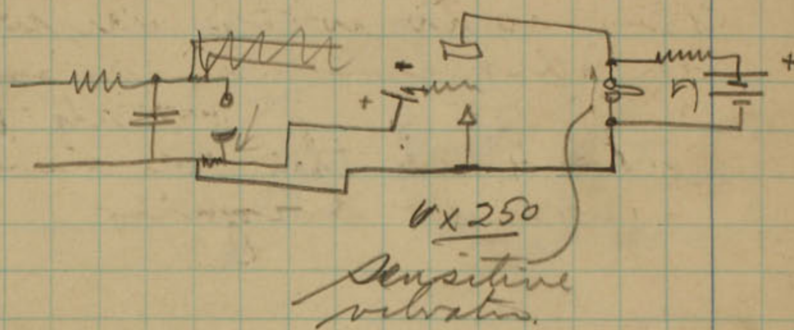


1×10^{-2} farads. ±

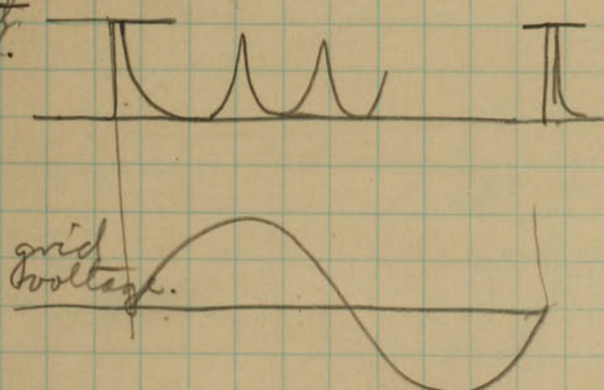
10^{-11} amp of photoelectric current to a 1:1 tube of the G. E. Co. This is enough current to control a large thyratron

Measure of current after main discharge by means of oscillograph and V.T. amplifier. (Suggested by Nottingham)





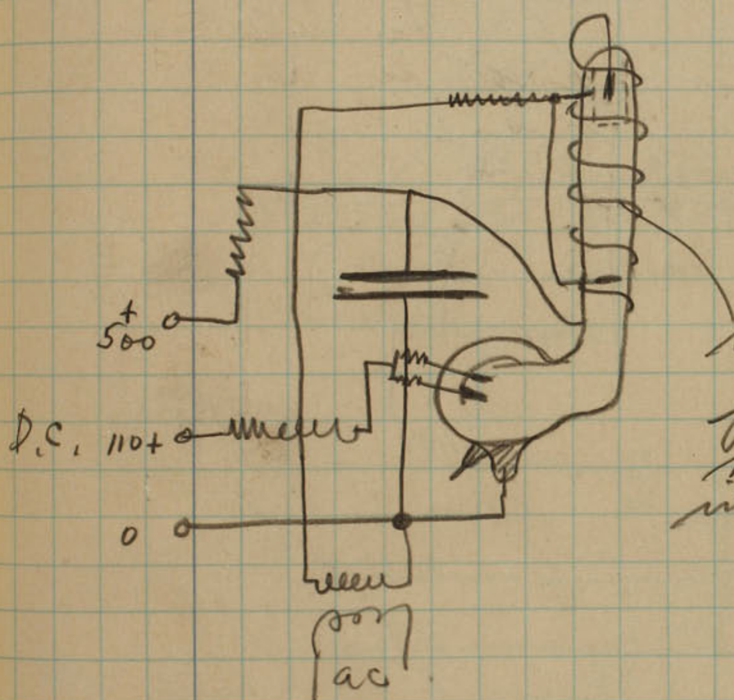
The main flash would increase the neg bias to cutoff or more. Then the rest of the phenomena would come through.



Feb 17 1931.
H E Edgerton.

One experiment I wish to try is to wrap the wire carrying the discharge around the stroboscopic tube. I think this will speed up the discharge and possibly make it brighter.

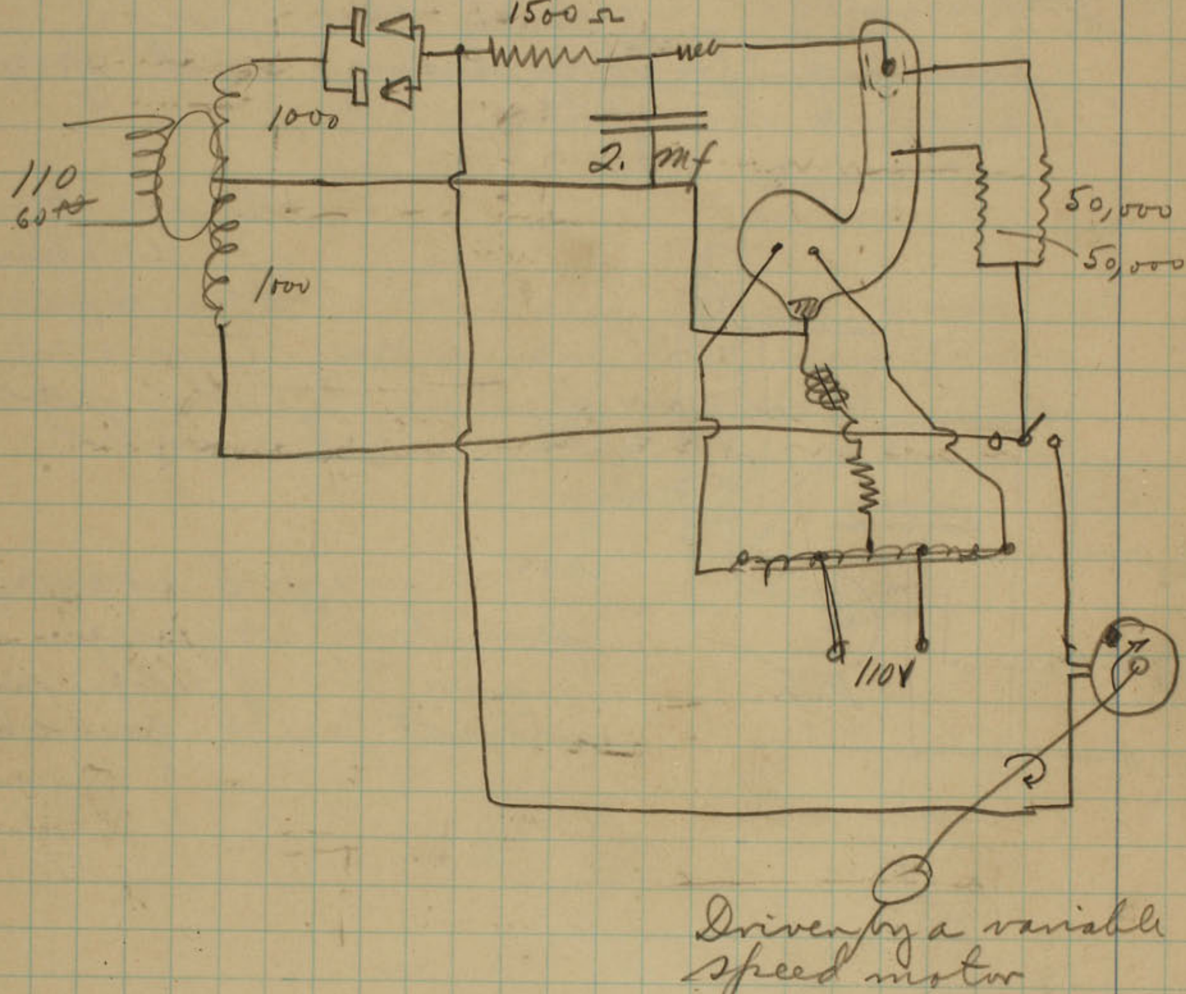
Killian Grey and I exhausted the special stroboscopic tube last night.



wire wrapped around the positive column to make the flash more intense and quicker?

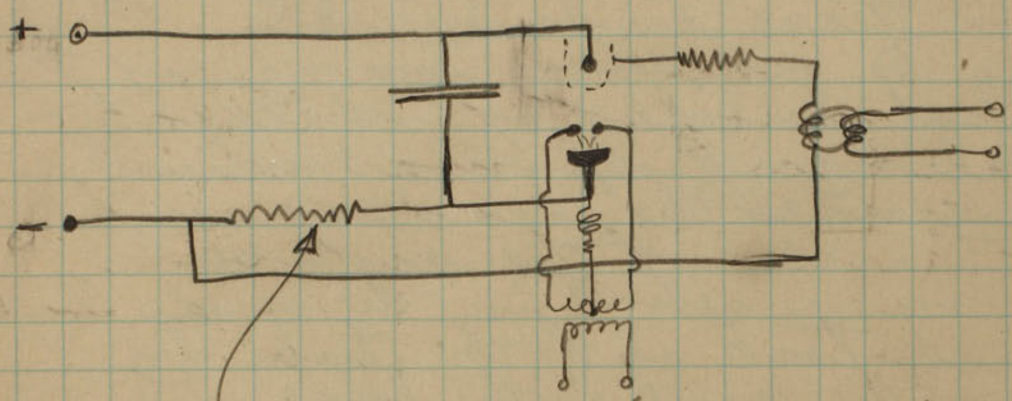
Mar. 2, 1931

The demonstration at the hotel Statler for the M. I. T. Alumni went off fine last saturday night. I had the stroboscope on all a-c and it worked fine.

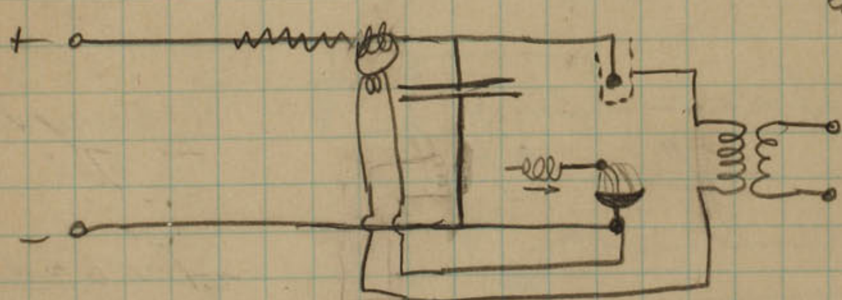


Mar 9, 1931.

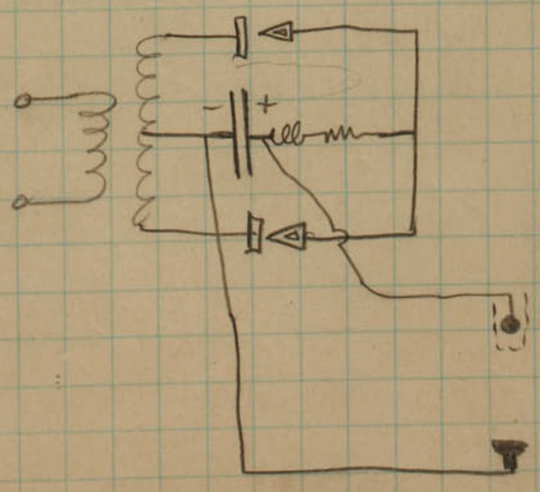
Methods of eliminating ghosts that trail the main discharge.



The drop through this resister acts as a bias on the grid circuit.



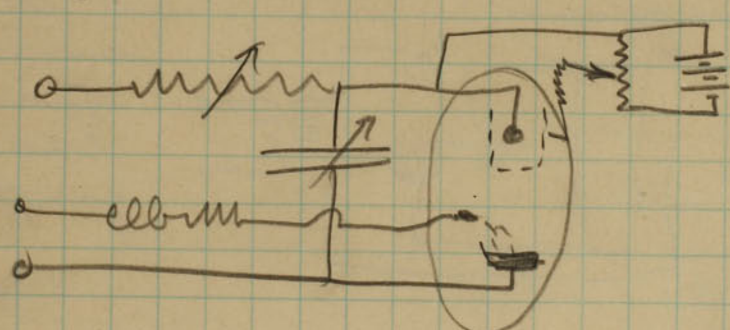
In this circuit the charging current gives a neg. bias to the grid.



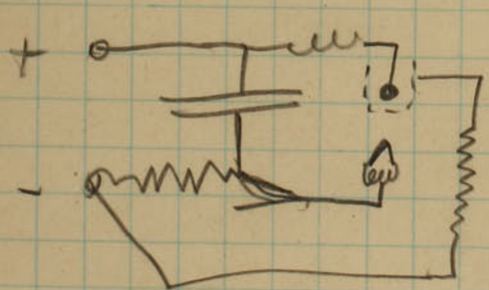
Mar. 15, 1931

On ~~last~~ Saturday I connected up the stroboscope to take some movies of the vibrating molecule of benzene which Prof. Andrews of Johns Hopkins had ~~[illegible]~~ at Harvard. Reisner helped me in these experiments. We were trying to get some movies of the critical modes of oscillation the balls and springs which represented the masses and elastances of the molecule. There was a short in the anode lead and it took out the tube by cracking the seal in the base.

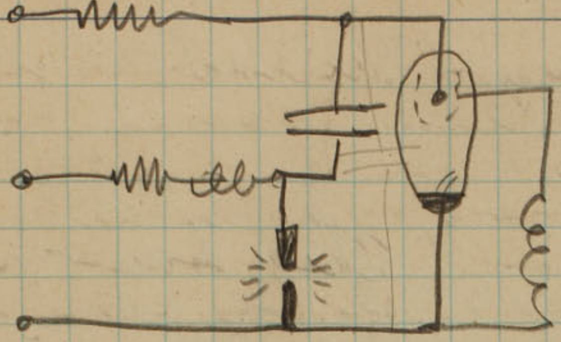
Scheme showed to Reisner to make a tube oscillate. ~~—~~ this thyratron had a grid with a large spacing and it was very hard to control.



Connect grid to the anode and bias by means of a battery.



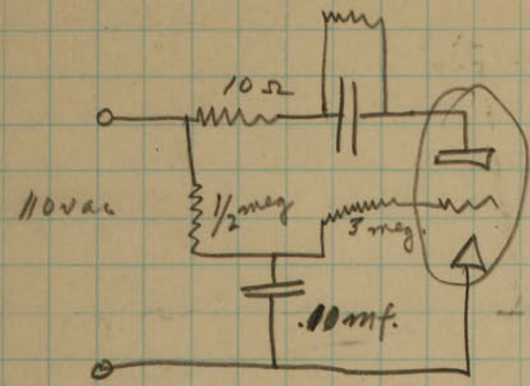
Oscillator.



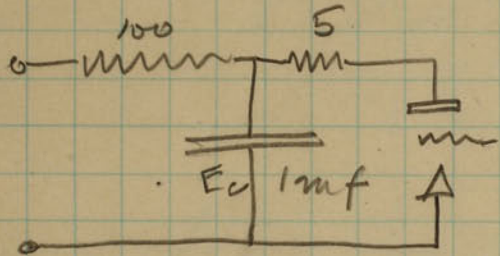
Thyratron as a switching arrangement for air arc

March 30, 1931.

Stroboscope for the lab.



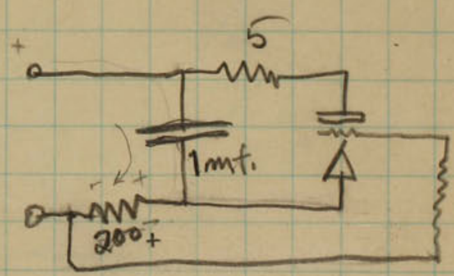
This draws a large current from the line to charge the condenser and the current gives light as it passes through the tube.

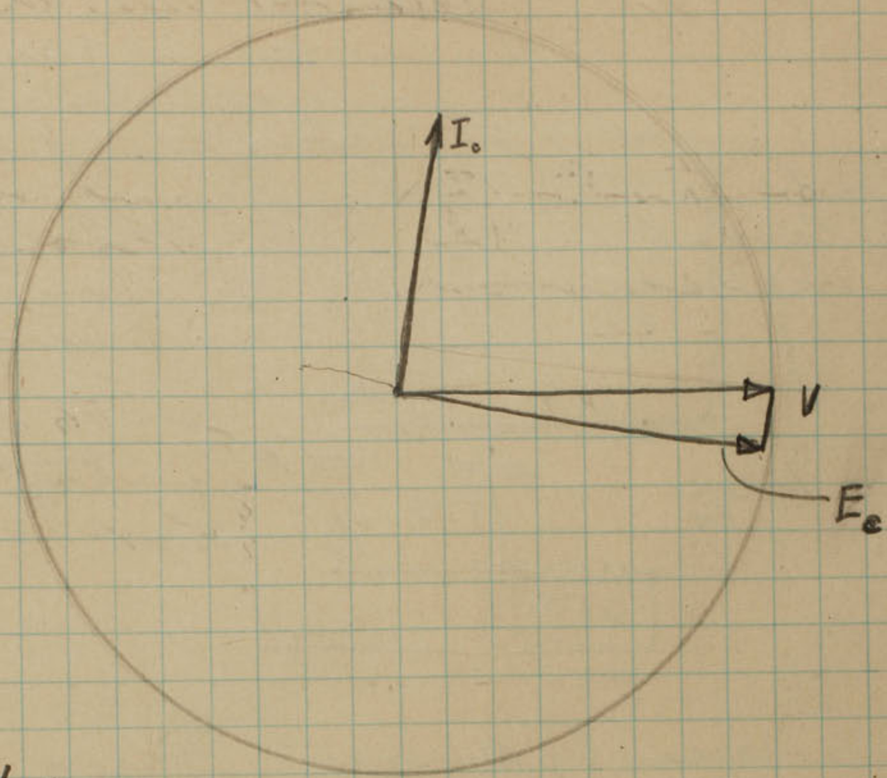


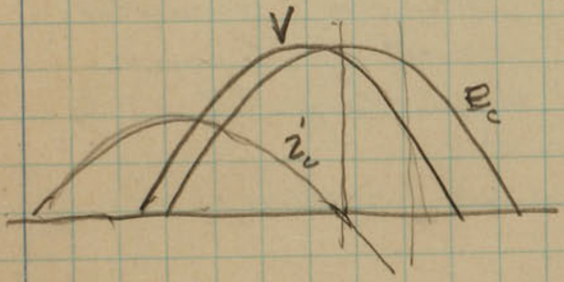
1000 2000

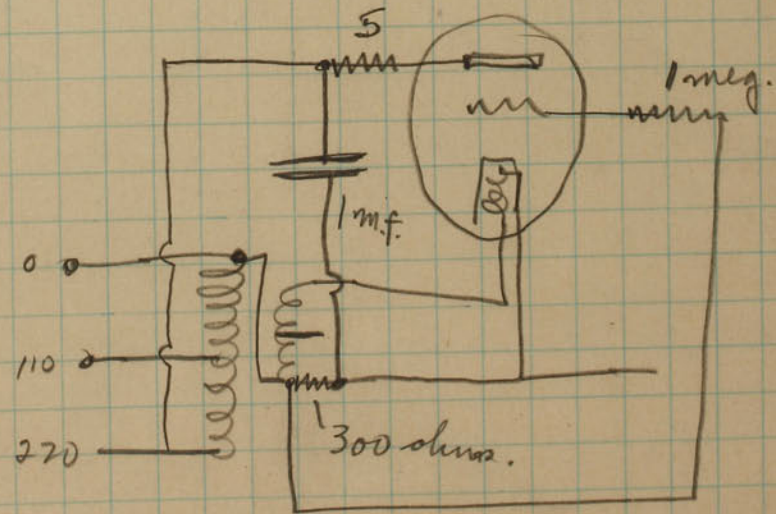
.05 amp.
2000) 110.00

5 volts.



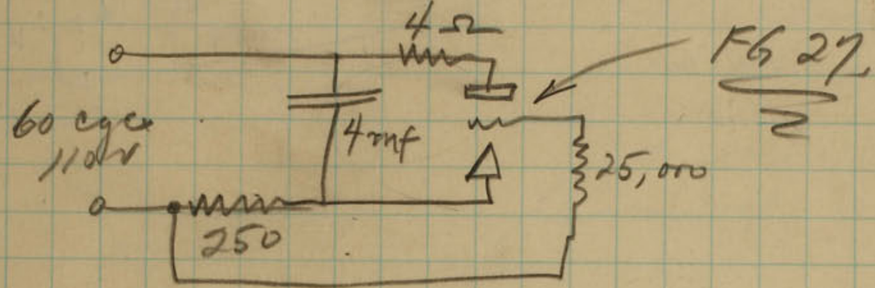

I₀
V
E_c


V
E_c
i_c

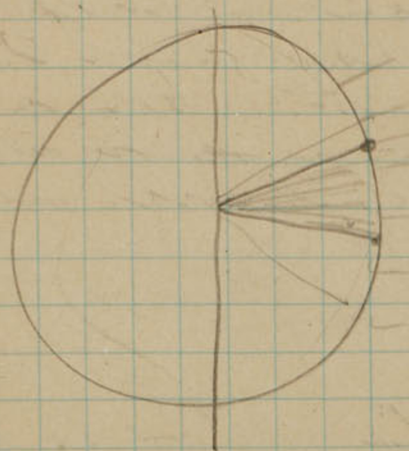

5
1 meg.
1 m.f.
0
110
220
300 ohms.

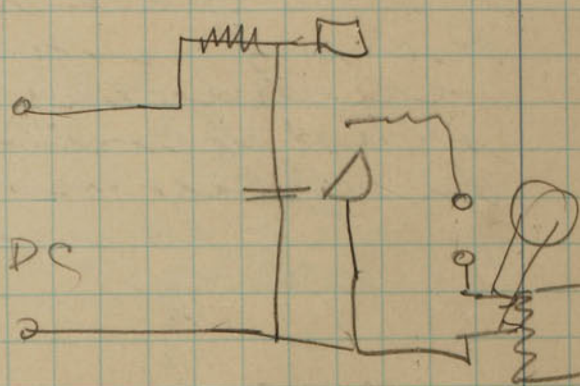
April 1, 1931
H.E. Edgerton.

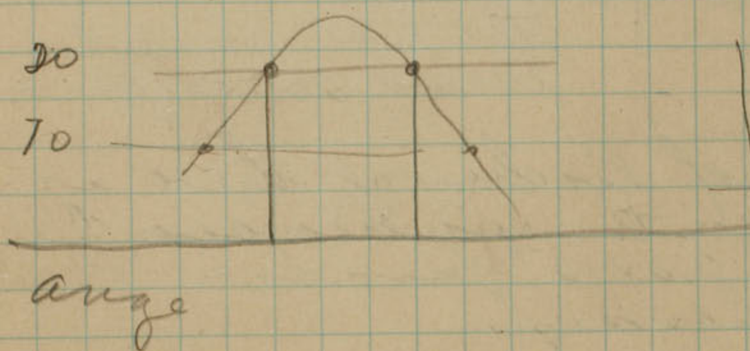
The scheme shown on the preceding pages gives a very convenient stroboscope. In the lab tests today and yesterday I ended with the following arrangement.

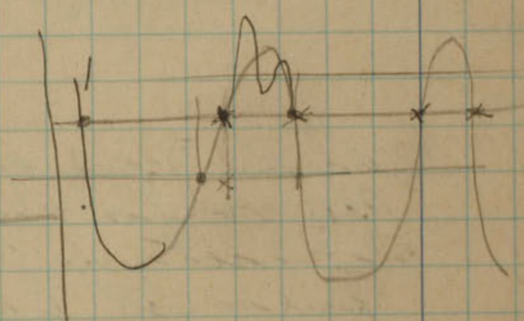


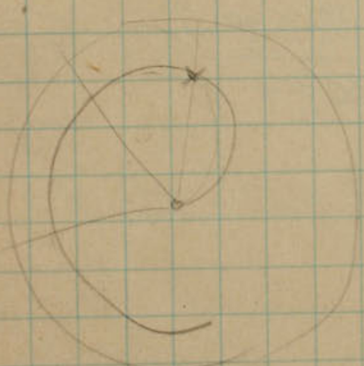
It was seen by Norcross, Gage, Dawes, Lane, Pritchard, Outt, and others. I am planning to put one together permanently for the lab.
Tucker and Hentz saw it. Rose also.




DC

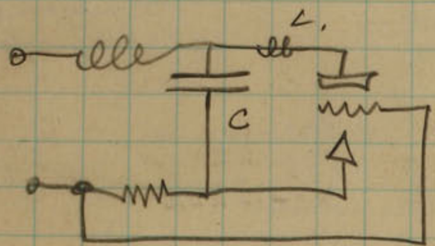

80
70
ange





April 16 1931

The efficiency of the circuit on page 100 can be improved by using an inductance in the discharge circuit instead of a resistance. Also an ~~resis~~ inductance in the charging circuit will make the voltage across the condenser greater as well as improve the efficiency.



Calculation to give size of inductance.

The current through the tube should not exceed 25 amperes.

At the time of discharge there is 150 volts on the condenser. The capacity is 6.0×10^{-6} farads in the present hookup.

$$E1 = \left(Lp + \frac{1}{Cp}\right) i$$

$$i = \frac{E1}{Lp + \frac{1}{Cp}} = \frac{E\,c\,p\,1}{LCp + 1} = \frac{E}{L}\left(\frac{p\,1}{p^2 + \frac{1}{CL}}\right)$$

We know from operational calc. that

$$\frac{p}{p^2 + \omega^2} 1 = \frac{\sin \omega t}{\omega}$$

therefore

$$i = \frac{E}{L} \frac{1}{\sqrt{\frac{1}{LC}}} \sin \omega t$$

The max current occurs when $\sin \omega t = 1$

$$i^0_{max} = E\sqrt{\frac{C}{L}} \text{ amperes.}$$

with $E = 150\,v$

$C = 6. \times 10^{-6}$ farad

$i_{max} = 25$ amp.

Solve for L.

$$L i'^2 = E^2 C$$

$$L = \frac{E^2 C}{i'^2}$$

$$L = \frac{150^2 \; 6.0 \times 10^{-6\,-2}}{25^2} = .000215 = 0.215 \text{ mh.}$$

The discharge frequency.

$$f = \frac{\omega}{2\pi} = \frac{1}{\sqrt{LC}\;2\pi} = \frac{1 \; 10^6}{2\pi\sqrt{215 \times 6.0}} = \frac{10^6}{2\pi\,36} = \frac{10^6}{226} = 4500 \text{ cyc/sec.}$$

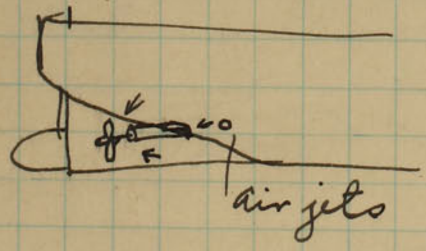
April 18 1931
H.E. Edgerton

When in Schenectady yesterday I disclosed to Mr. P.L. Alger and Mr Rich the stroboscopic switching scheme shown on page 78 and 79 of this book.

I plan to write them a letter giving the details of the scheme showing how it can be accomplished.

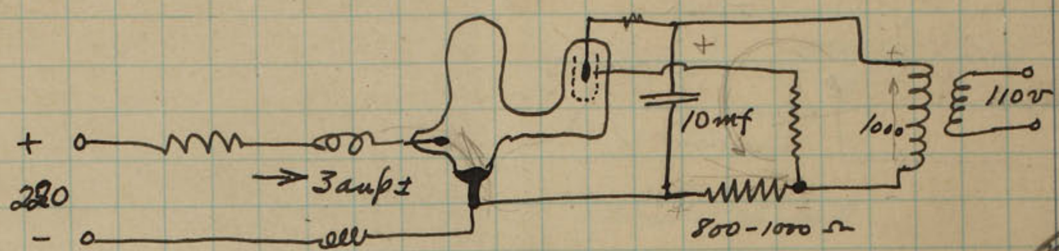
When riding from the plant with Mr. Alger and Mr. Emmet there was discussion by Mr. Emmett regarding the electrical drive of the large battleships. He was interested mainly in the torques that are necessary to reverse the propellers.

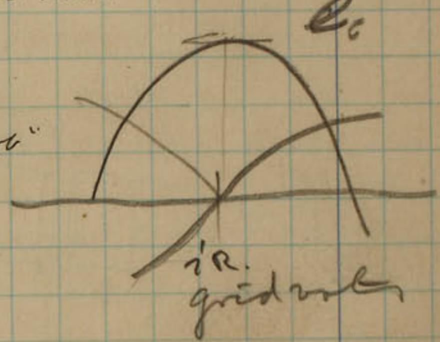
It occured to me that the propellers might be reversed more easily if compressed air was blown into the water ahead of them so that it struck the propeller. This might help the propeller break the water into turbulence so that it could reverse more easily.



Apr. 29 1931
H. E. Edgerton.

Circuit for Stroboscopic observation of 160 HP motor in Dynamo Lab.



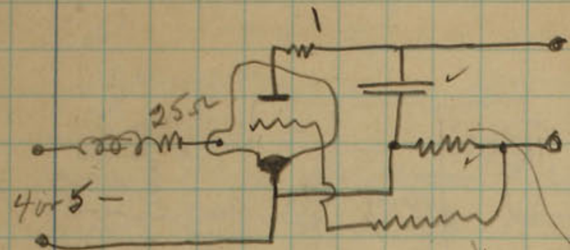


April 29 (Wednesday) 1931 E. L. Bowles — Witnessed actual operation of this circuit in "dynamo-lab" M.I.T.

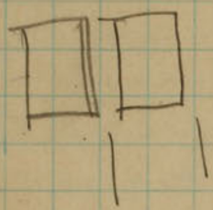
After seeing the above circuit work Bowles and I went over to the Engine Lab. and saw the indicator that Draper and Taylor set up. This used a circuit that I showed Draper several months ago which discharges a condenser through a spark coil. The circuit is actuated by a grid contact made by a pressure membrane inside the cylinder. The thyratron circuit regains control because of action of the parallel condenser across the tube.

May 4 1931

Talked with Draper about photographing jet of vapor.



ac 500 volts 5000 cycles,



$\frac{1}{5000}$ sec to mm. 8 mm.

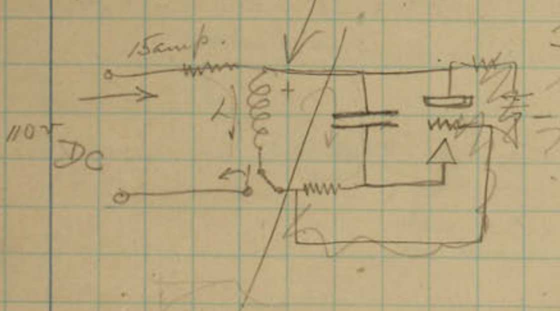
1 sec $8 \times 5000.0 = \frac{40,000}{25}$ mm =

1500 in sec.

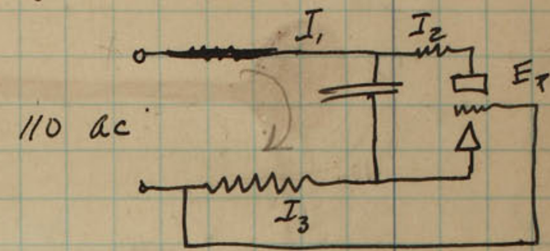
100 ft sec.

1.9 lens.

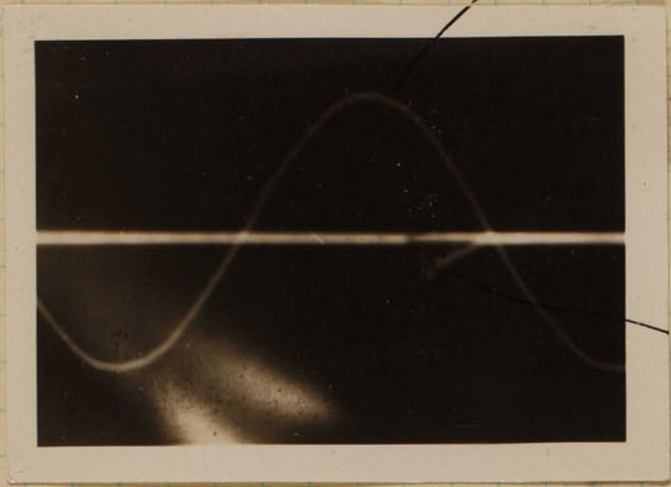
Scheme from Dr. Bush which came up when talking with Draper. Choke to store the energy for a series of flashes. The freq. will be const and the light const?



May These were taken by two Juniors
Wagner and



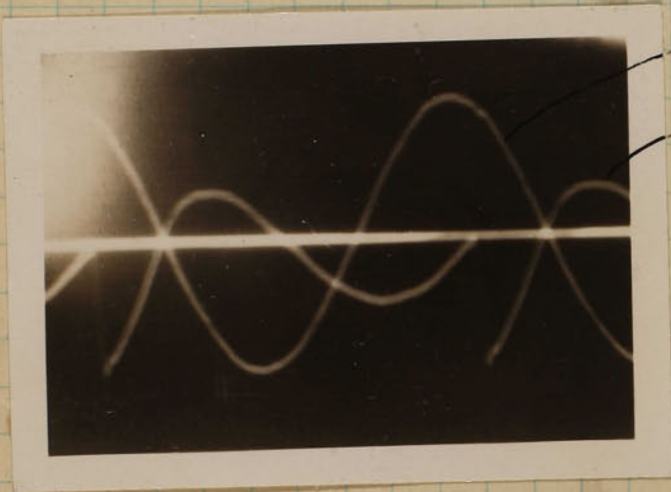
voltage

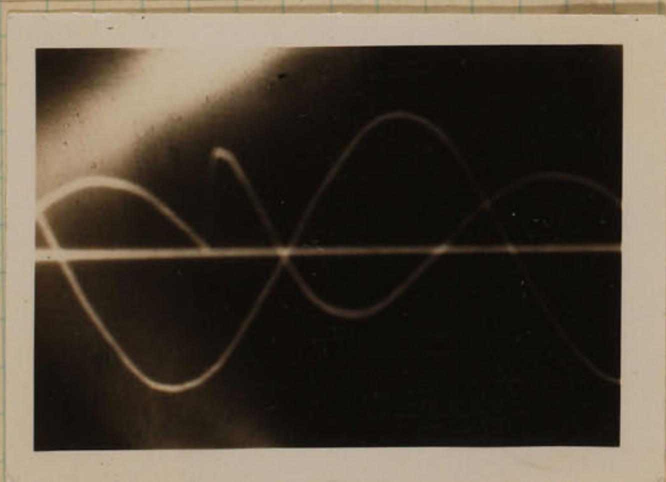


discharge current I_2

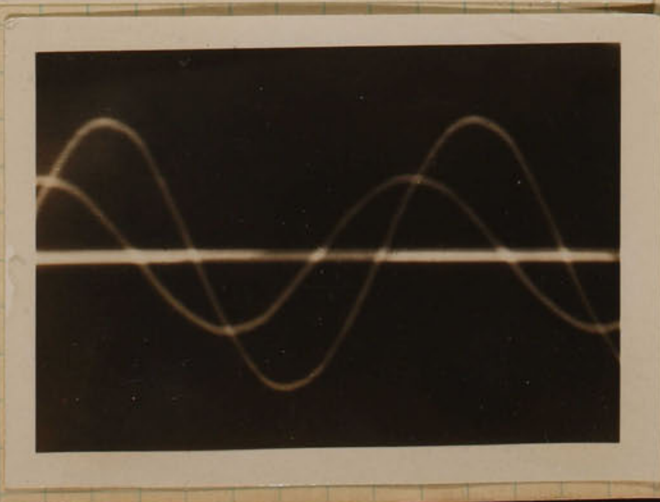
voltage

I_3 charging current (also grid voltage).





Ditto but with different phase relationship.



Current and voltage with the tube off.

Notebook Number: T-1

Scanning and Separation Record

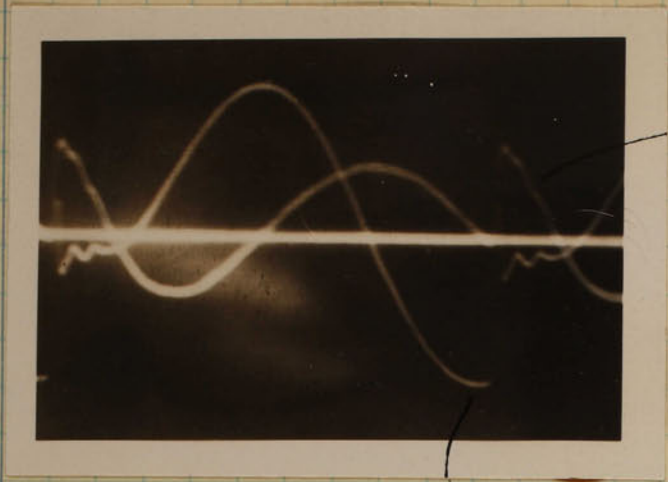
1 unmounted photograph(s)

____negative strip(s)

____unmounted page(s)
(notes, drawings, letters ...)

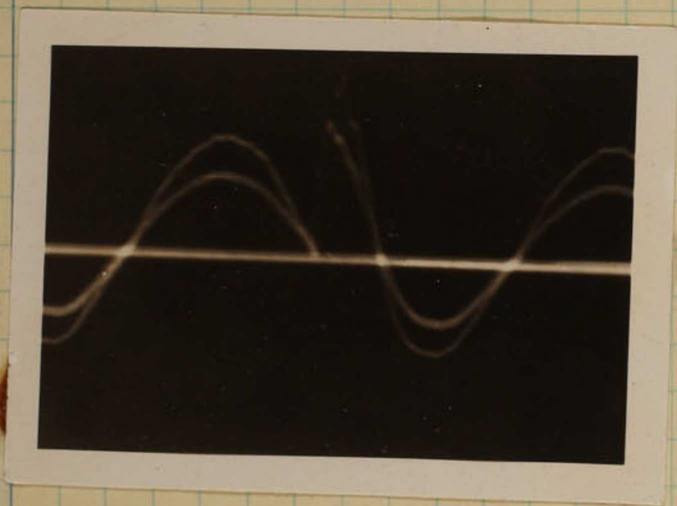
was/were scanned ~~where originally located between page~~ in place on page
108 ~~and ____~~.

Item now housed in accompanying folder in MC 25, box 166



charging current or grid voltage.

voltage E_p (anode to cathode).



Stroboscopic Moving Pictures

By means of moving pictures taken stroboscopically it is possible to see the rotor of a synchronous machine just as though one were actually revolving at synchronous speed with the rotating field of the stator windings. Newly developed thyratron tubes provide sufficient light for taking the pictures.

By H. E. Edgerton

Associate A. I. E. E

Massachusetts Institute of Technology
Cambridge

OF THE SEVERAL different methods of determining the very important, but rarely measured angular displacement of a synchronous machine, stroboscopic observation is the most direct and straightforward. This method requires a minimum of apparatus; namely, a disk rigidly attached to the shaft of the synchronous machine, a suitable stationary scale for recording the displacement, and an intermittent light source operating in time phase with the terminal voltage of the machine. The disadvantage of the stroboscopic method in the past has been that the measurements had to be recorded visually, and thus the accurate measurement of transient variations of angle has been practically impossible because of the inability of an observer to record the phenomena during the short duration of most transients.

With the stroboscopic device described in this article, enough light is produced so that a motion-picture record can be made of the angular displacement of a synchronous machine. A mercury vapor arc is used which produces the characteristic blue light well known for its powerful actinic properties. The tube used to produce the arc is a thryatron containing grids that control the electrical transients which are the source of the stroboscopic light.

Stroboscopic moving picture records will provide important observations for those who are concerned with the operation of synchronous machines. These moving pictures will be especially valuable when correlated with oscillograms taken simultaneously. The "strobograms," as these pictures may be called, will furnish power engineers with information regarding the angular displacements of their generators, condensers, and lines during switching and short-circuit disturbances. They will tell the users and designers of synchronous motors exactly how far the rotors swing, their period of motion, and the damping of their oscillations for violent, sudden load changes such as are common in the steel industry. Photographic records will be valuable also in studying the steady-state time-angle variations.

In addition this method of photographing stroboscopically illuminated objects will provide research workers with the means whereby many experimental investigations may be made. It is especially adapted for studying the motion of mechanical objects such as springs, cams, valves, and other devices.

Among the important requirements for a stroboscope suitable for photographic purposes, are:

1. Short duration of the light. If the illumination extends over an appreciable period of time the image will be blurred. A rough calculation shows that the duration of the main flash should not be longer than about 10 microseconds.

2. Rich actinic light. Photographic film is much more sensitive to ultra-violet and blue light than to red. For this reason a mercury discharge tube is used in place of the commonly used neon tube. The light from a mercury arc is composed of strong blue and ultra-violet colors. Some of the ultra-violet radiations are, however, absorbed by the glass walls of the tube.

3. Reliability of light-flash control. A synchronously rotating object viewed by a stroboscope will not be stationary if there is any variation in the interval of time between discharges in the stroboscope circuit. This time interval can be controlled very accurately by applying sufficient voltage to the thyratron grid.

Thyratron Circuit

An arrangement of apparatus capable of producing a powerful stroboscopic light is shown in Fig. 1. Current waves for various branches of the circuit are included also in this illustration. Light is obtained from a condenser discharge through the thyratron tube; and since the only impedance in the circuit besides the thyratron is that of the leads connecting the tube to the condenser this discharge is very rapid, lasting only about 10 microseconds or even less. An intense momentary light flash is thus obtained.

The sequence of events through a cycle ot operation will be described in detail. When the grid is negative no current is flowing from the main anode because the grid has the property of extinguishing the arc. Such grid action is contrary to the usually explained rules of thyratron operation but occurs here because of the low density of the anode current and the large condenser

S.M.P.E. June 31

in parallel with the arc. During this half cycle, current flows from the 500-volt d-c. source through the resistance into the condenser in the well-known exponential relationship. The resistance and capacity are adjusted so that the potential across the condenser becomes practically 500 volts during the half cycle that the grid is negative. Replacing the resistance R with inductance L, or using both in series with the condenser, will give a still higher voltage across the condenser, if R, L, and C have proper values.

At the end of the charging half cycle, the grid becomes sufficiently positive to allow current to flow from the anode. The charge that has been accumulated in the condenser will then be discharged through the tube. If short, heavy-stranded leads are used to connect the condenser to the tube the holding arc may be extinguished at this time by the condenser discharge, but this difficulty may be overcome by introducing a choke coil into the holding circuit and a small resistance in series with the condenser. From a recent study by Krug, (of the arc striking speed of a mercury arc rectifier), (*Arch. f. Techn. Physik 11*, 1930, 6 p. 227, and *E. u. M.* 48, June 8, 1930, p. 567), it is known that only 0.01 to 0.1 microsecond is required to start the arc. Thus the thyratron acts virtually as a short circuit across the condenser.

For the remainder of the half cycle following the condenser discharge the grid is positive and the main anode carries a current which is limited in value by the resistance R. The light from this current is not intense and is negligible in comparison with the condenser flash. With the pool-type of thyratron this current is oscillatory under some conditions, giving faint ghosts trailing behind the main discharge. A negative bias and a peaked a-c. voltage on the grid eliminates these oscillations.

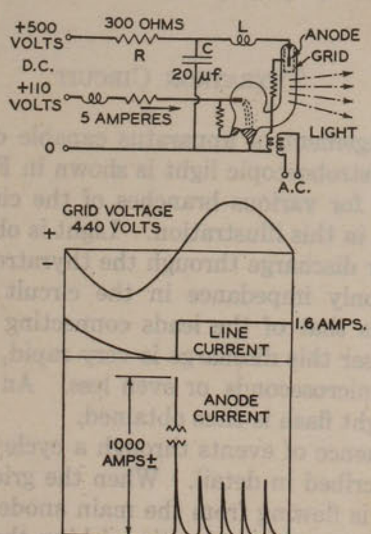


Fig. 1. Schematic diagram of thyratron circuit; voltage and current relations in various parts of the circuit are shown below

At the completion of the operating cycle the grid again becomes negative thereby extinguishing the anode current. The condenser then begins to accumulate a charge for the next flash.

Strobograms Taken

With the thyratron and other apparatus just described, a 160-hp. synchronous motor was photographed stroboscopically as it pulled into step. The tube was hung on a framework so that its light would fall directly upon the field structure. White cardboard collars were tied around the poles and alternately marked "*N*" and "*S*." The amortisseur rings were painted white and the protruding bars black. A general view of the arrangement in operation is shown in Fig. 2.

Strobograms taken during the transfer from operation on half voltage, which was used for starting the motor, to full voltage, are shown in Fig. 3. These consist of a sequence of enlarged, 16-mm. moving picture frames and were taken on panchromatic film at 16 frames per sec. with a lens opening of f-1.9.

The particular thyratron used for these tests had two anodes, each was connected to a circuit such as shown in Fig. 1 but the grids were supplied from a common transformer. No apparent difference in the

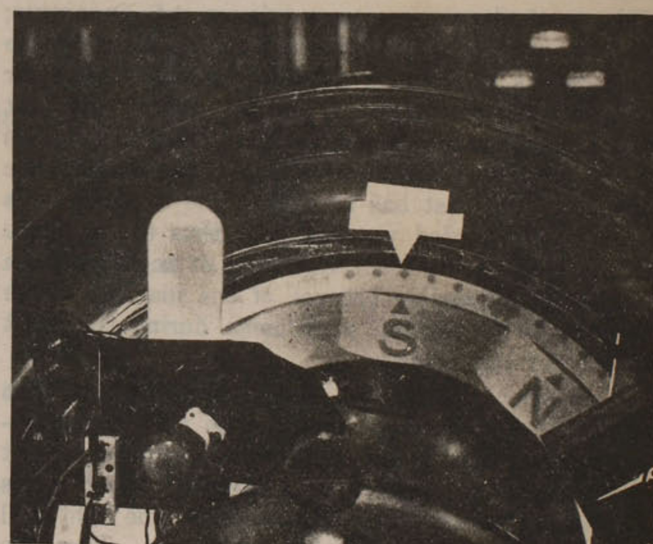


Fig. 2. Thyratron arranged for taking stroboscopic movies of a 160-hp. synchronous motor

time of discharge was experienced, except when the tube was cold.

A special camera which would record the rotor displacement angle for each cycle could easily be made. This camera would require no shutter and no mechanical framing movement. The film could be run through the camera at a constant speed and just fast enough so that the exposures would be spaced correctly.

A simultaneous reading of time could also be taken with the angle on the strobograms by photographing a clock hand driven by a telechron clock motor running

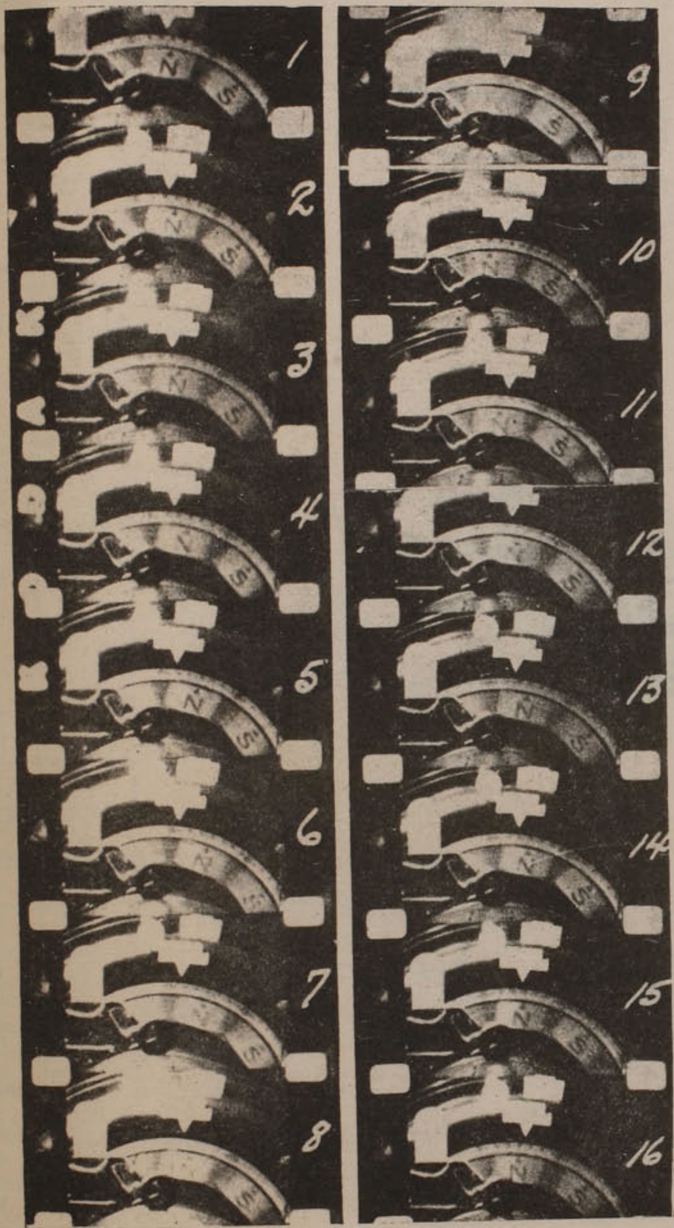


Fig. 3. "Strobograms" of a synchronous motor as it was switched from half to full voltage. Increased angular displacement may be noted as the supply switch was momentarily open during changeover (4-7)

at one revolution per second. This would be quite necessary for accurate testing since there is no definite relation between the frequency of the camera shutter and that of the intermittent light.

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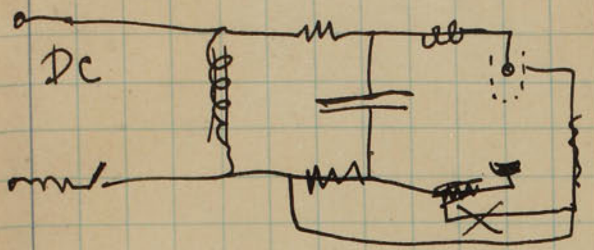
May 21



wont work.?

Energy $= \frac{E^2C}{2}$

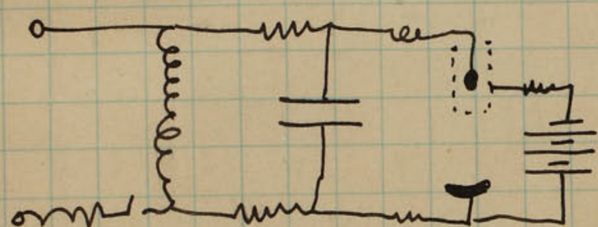
$= \frac{400^2 \times 40 \times 10^{-6}}{2}$

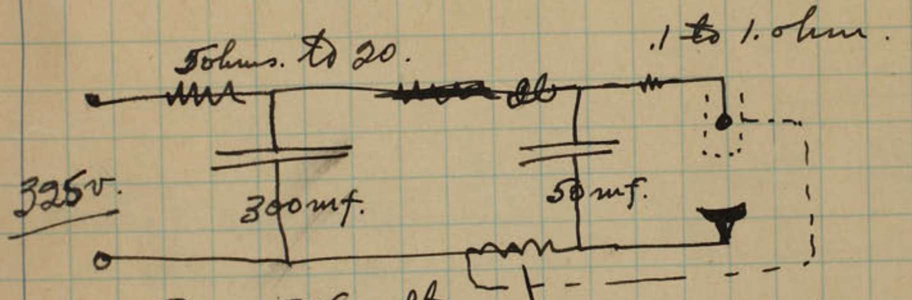
$=$ 3.2 joules.

$\frac{LI^2}{2} =$ 3.2 joules. $I = 15$ amp.

$225 \overline{)1.000}$ .007

$L = \frac{3.2}{2 \times 15^2} = \frac{3.2}{2 \times 225} = .007\,h.$





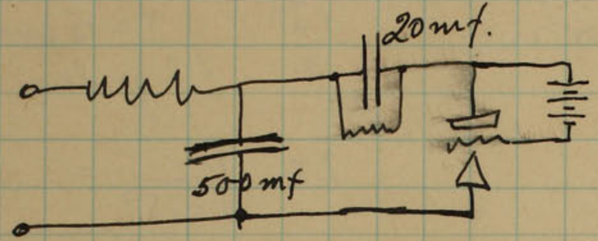
$230\sqrt{2} = 325$ volts.

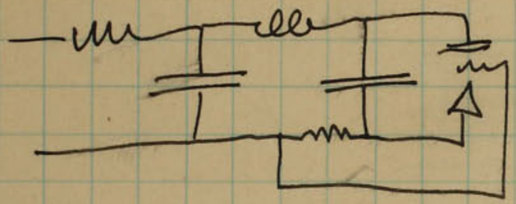
$8 \times 100 = 800$ mf.

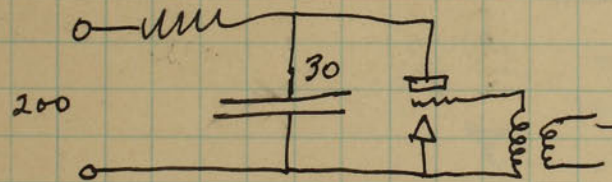
May 22, 1931.

Talked to Prof Taylor and to Draper about stroboscope for photographing jets from a diesel engine.

Other circuits.





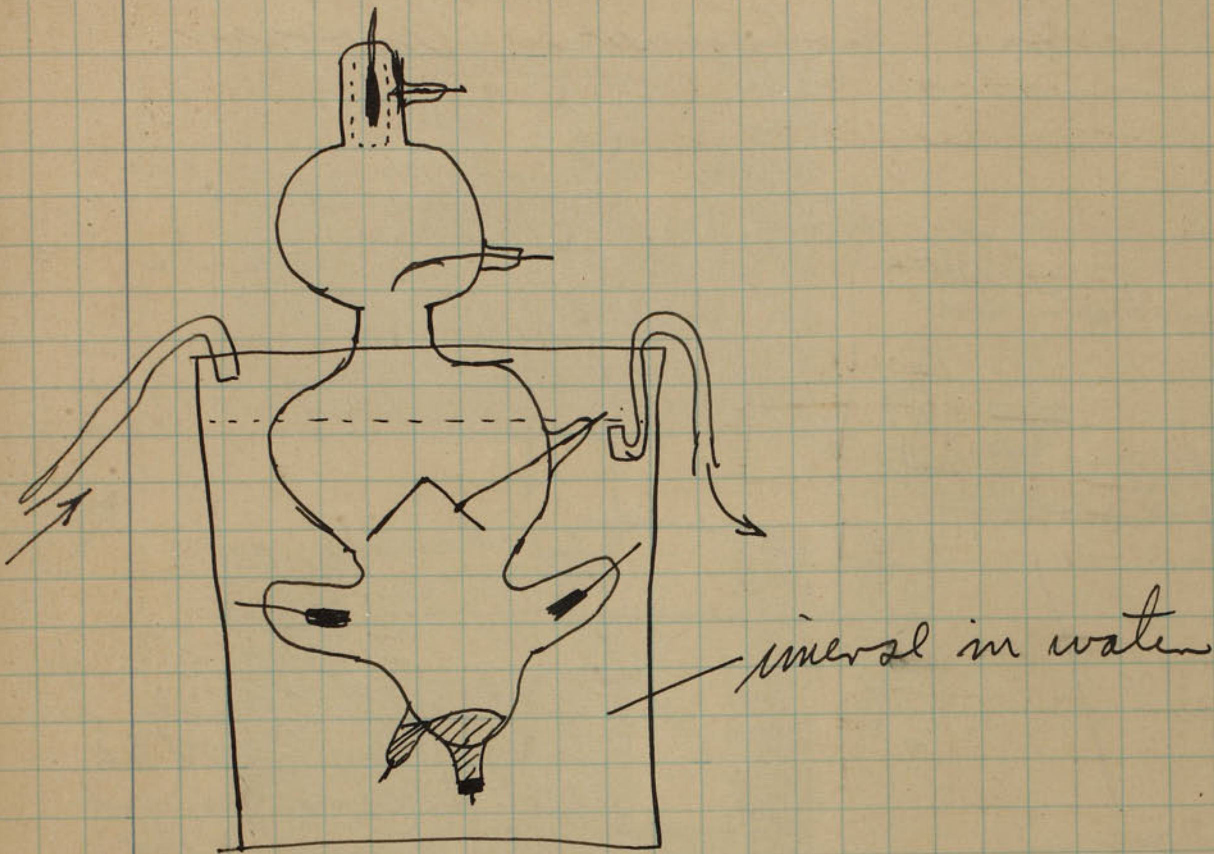


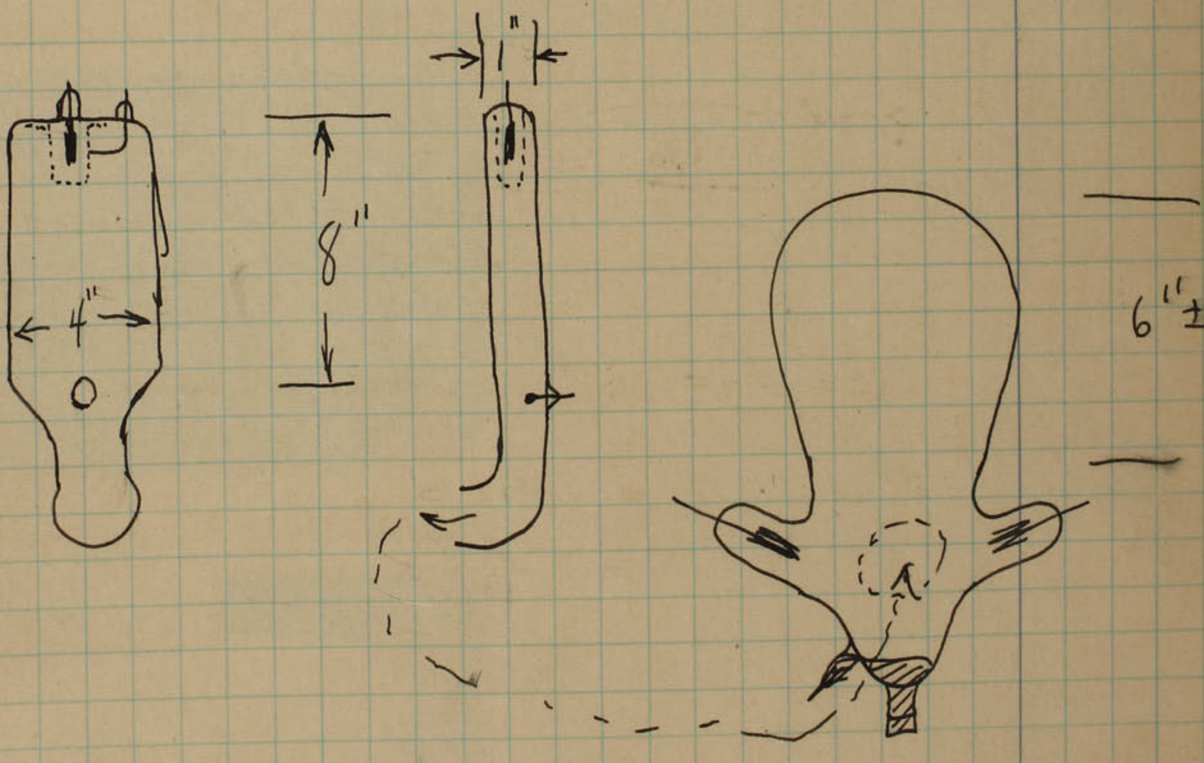
— Thyratron oscillator.
5000 cyc. sec.

$RC = \frac{1}{.5000} = 2 \times 10^{-4} = .0002$ seconds.

30 mf. $RC = .0002 = 2 \times 10^{-4}$

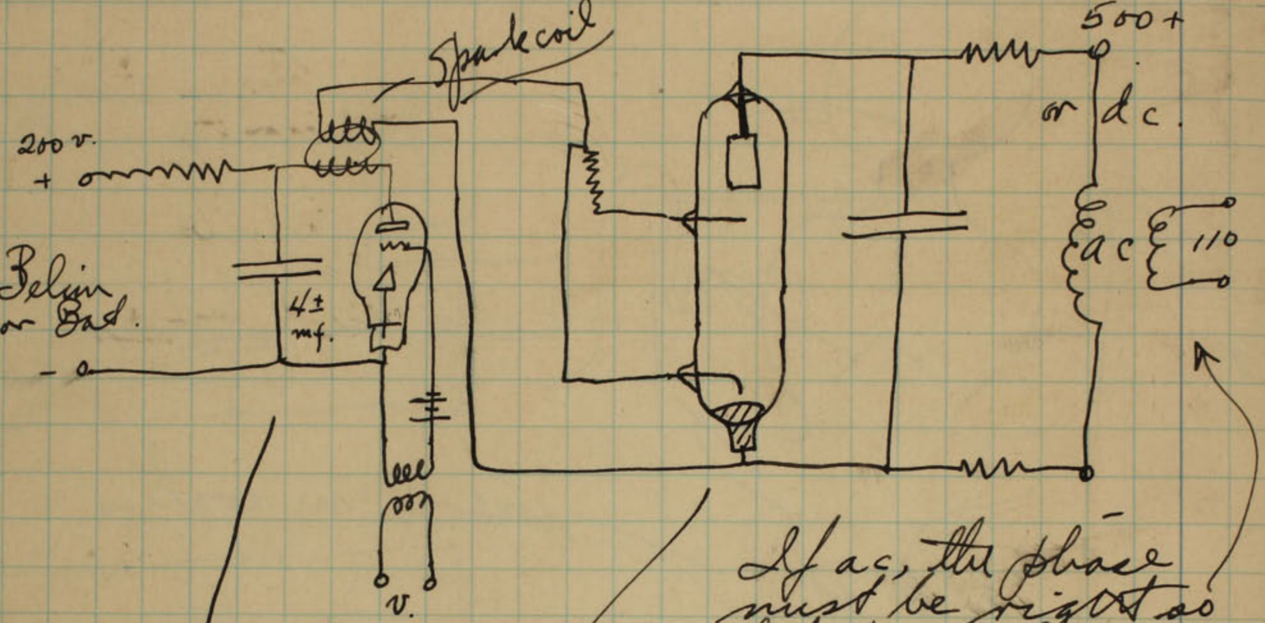
$R = \frac{2 \times 10^{-4}}{30 \times 10^{-6}} = \frac{10^2}{15}$ $15\overline{)100}$ 7 ohms. 7 ohms.


imersed in water


4"
8"
1"
6"±

May 23 1931
H E Edgerton.

High-Power Stroboscope for Photographic Purposes. at 80 cycle per sec.

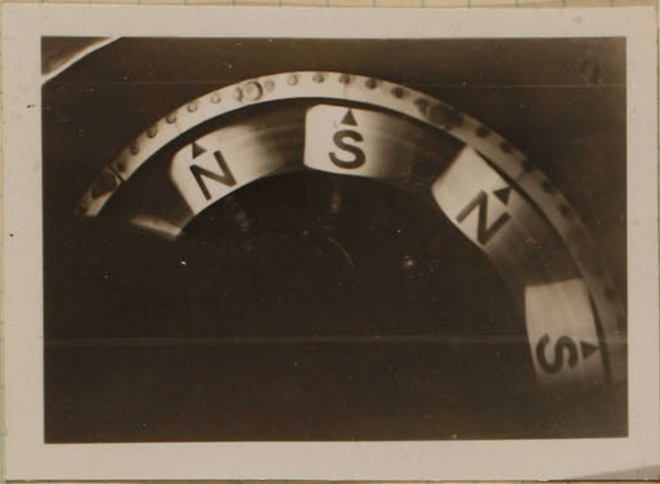


The all a.c. circuit can be used here.

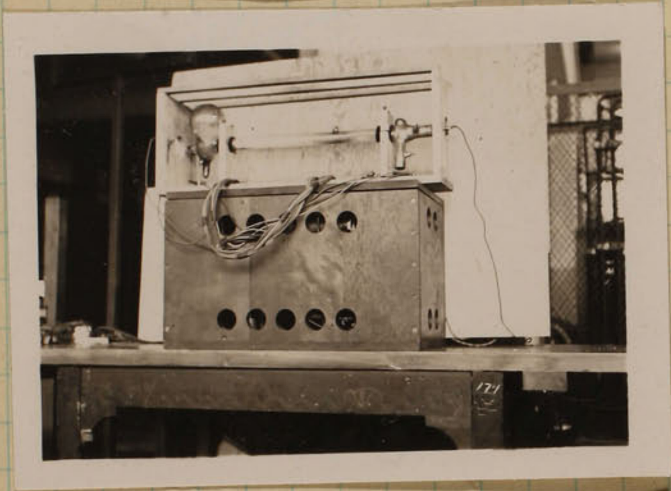
If a.c., the phase must be right so that the condenser is charged + for the flash.

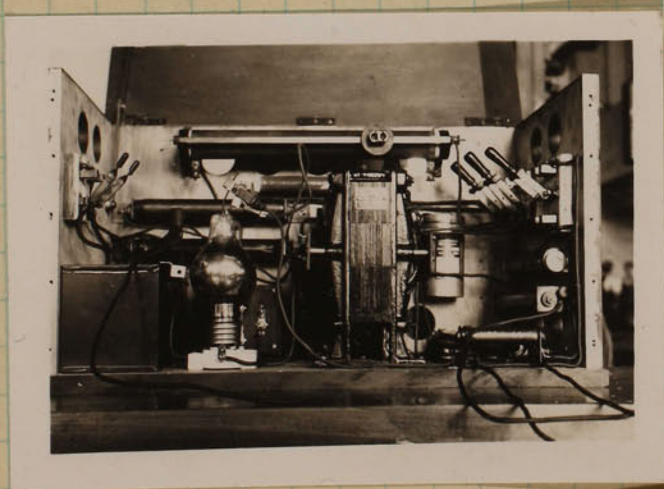
No holding arc is needed. The discharge is started by the spark from the condenser discharge through the spark coil.

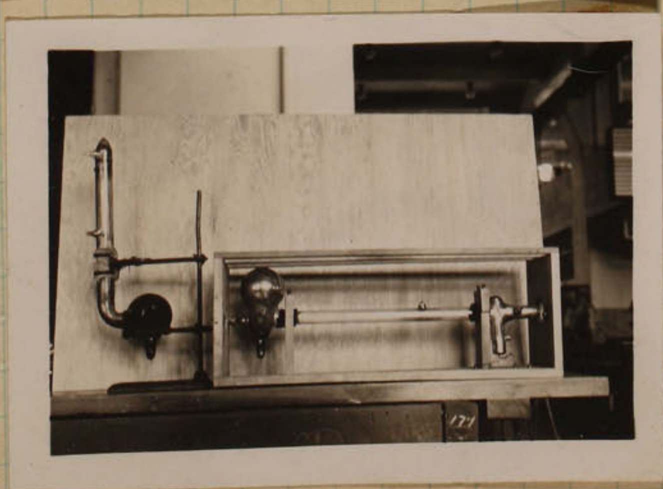
May 28, 1931.
H. E. Edgerton
20 sec exposure of 160 HP motor.



These pictures were taken by McClure and Stauder and were put in their thesis. 1931.

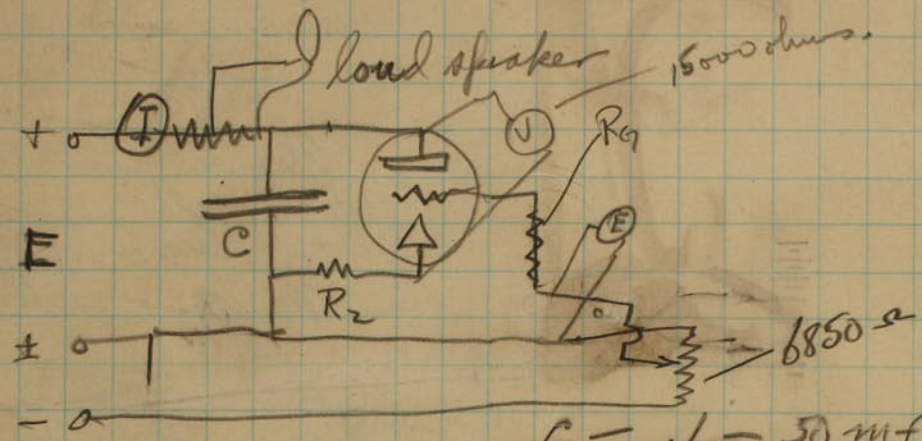






May 28 1931

thyratron Osc. Char. with Parallel condensers.



FG - 27 (Gassy)
- 17
- 67
- 33
- 29.

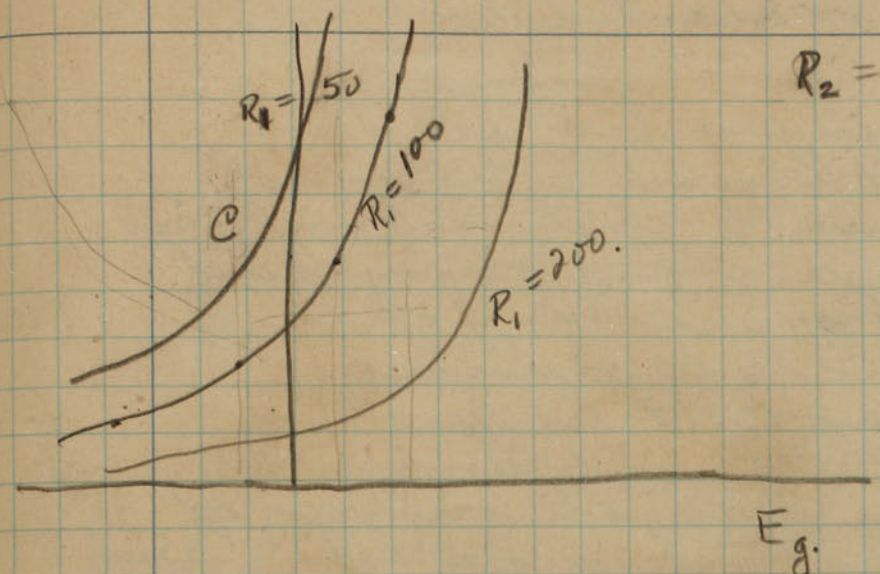
C — .1 — 30 mf.
R2 — 4 — 30 ohms.
RG — .01 to 10 megohms.

May 29, 1931

FG - 17

E	SOCKET temp.	R_1	R_2	R_G	C	E_{drop}	E_G	E_{gm}	I	freq.
110	61.5	—	7	30,000	.1	13.5	-84	(-4)	.1	—
110					.2		79			
					.3		75			
					.5		85			
					.7		92			osc.?
					.9		100.			
	63.0				.1		-92			
					2.2		req more than -112 v			
112	63.9	—	7	10,000	.9		-105			
Cannot put out arc					.1	14.9	—		.2	
					.5		—			
	63.				2.7		—			
	65.8	—	5	10,000	.3	16.9	-28		0.1	
	.		5	20,000	.3	"	50		.1	
			5	30,000	.3		77		.1	
			5	40,000	.3		101		.1	
	65.7		5	50,000	.3		more than 112		.1	
			5	10,000	.3		" " 112.		0.2	
			2	10,000	.3		" " 112		0.2	
			1	10,000	.3		" " "		0.2	
	arc goes thru bottom of grid.		1	10,000	.3	17.5	112		.06	
			1	10,000	.3	12.7	-16		0.1	
			1	30,000	.3		-40		0.1	
			1	60,000	.3		-80		0.1	
	65.9		1	10,000	.6		-14		0.1	
			1	30,000	.6	13.5	35		.1	
				60,000	.6		67		.1	
unstable. →			1	60,000 -100,000 OK.	.9		-24.5		.175	

Nothing apparently in the phenomena. Rattling going out by loud speaker.

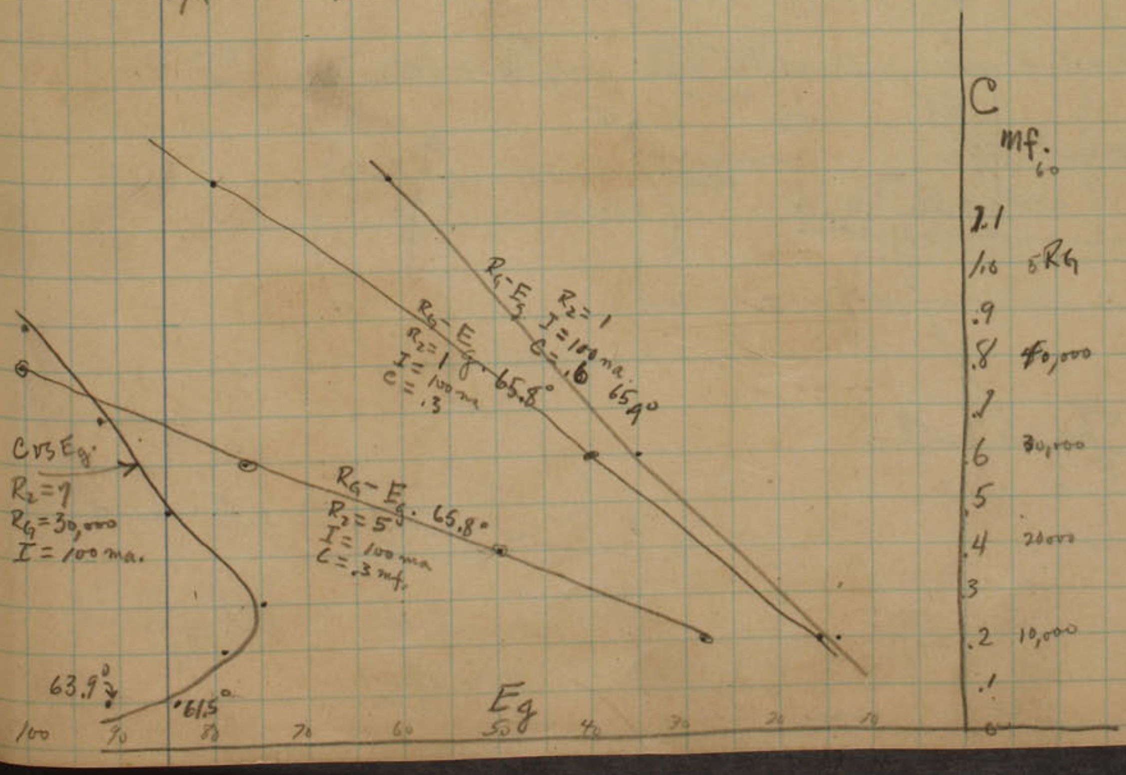


$R_2 = 4$ ohm.

Expected Results.

$$\frac{44}{25}\quad \frac{1.9\,v}{4000} = .05\text{ ma.}$$

E	t	R_2	R_G	C	E_{drop}	E_g	E_g out	I	Remarks.	I_g/I
112	73.2	1	10,000	.3	14.	112 mor than		0.10	did not go out.	
				.3		-40		.08		
				.6		-40		.08		
				.9		-76		.08		
				.9		-48		.10		
	71	1	10,000	.99-2.1		-112		.20	oscillates	
			70,000	"		"		.20	does not ..	
	69.3	1	9,990	.99		-45		.10		.05 ma.
			8,990	.99		40		.10		
			7,990	.99		36		.10		
			5,000	.39		12		.10		
			"	.39		112+		.15	did not go out	
			"	.99		25		.12		
	69.1		9,000	.99		44		.12		

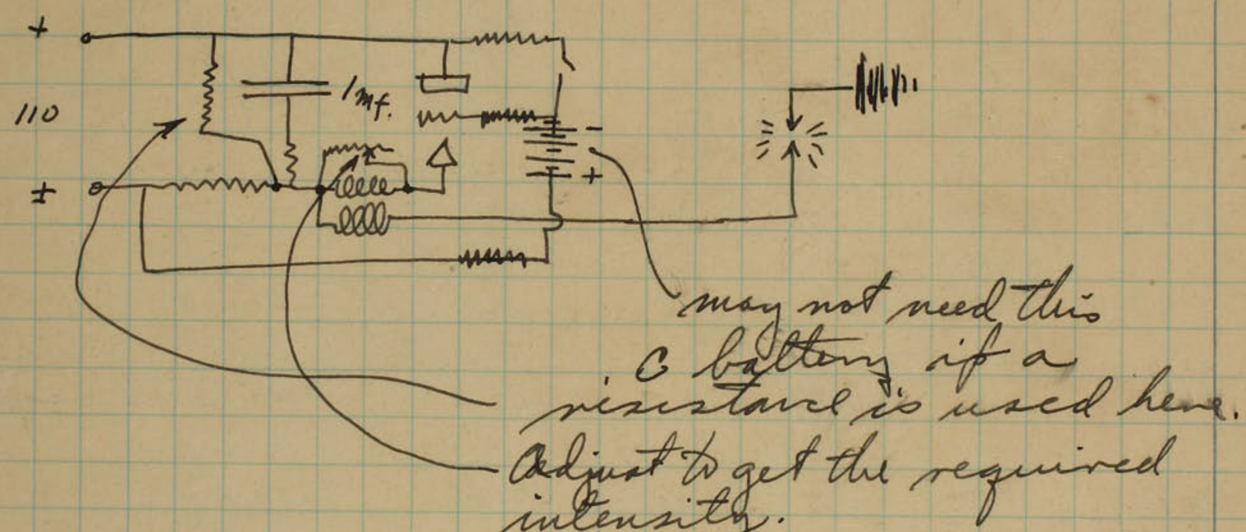


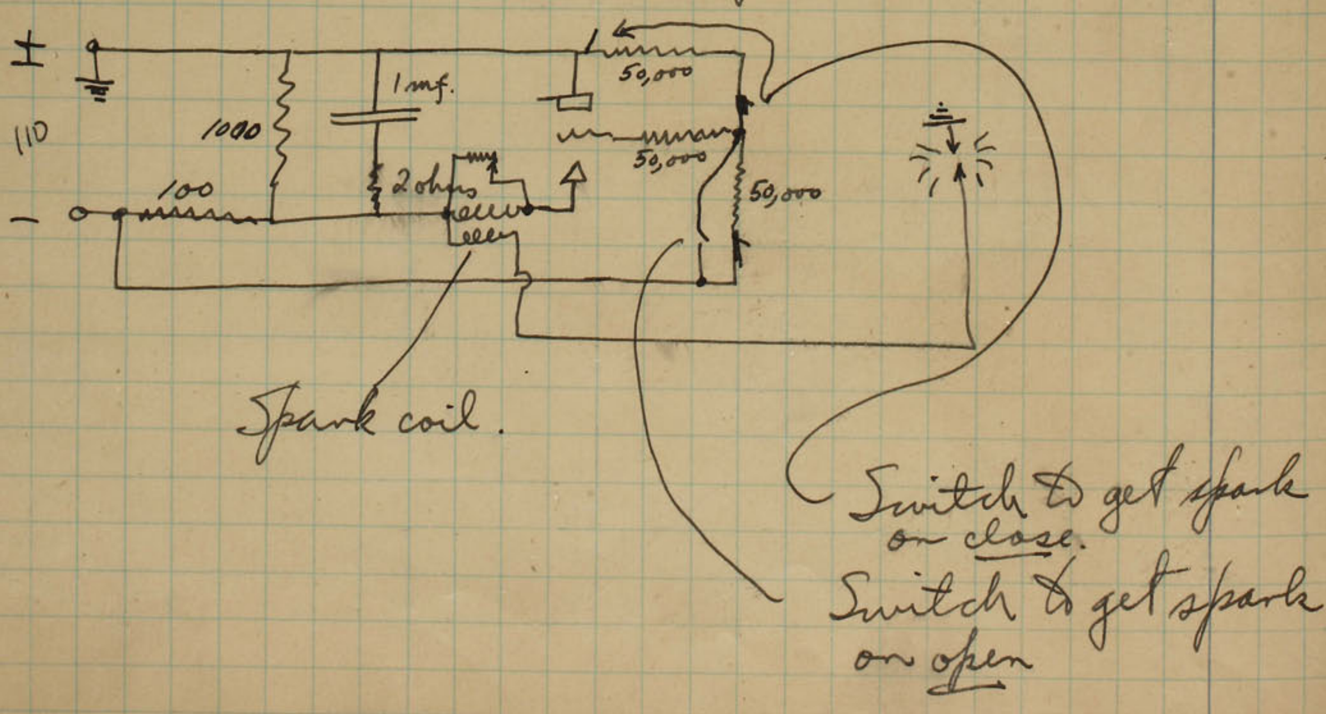
these tests to be repeated with the spark coil in the secondary circuit.

May 28 1931
H. E. Edgerton

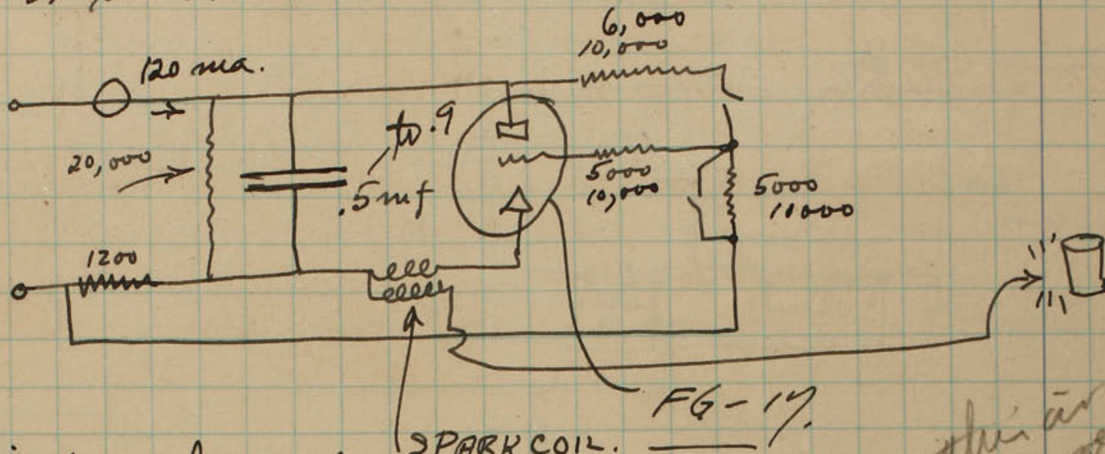
Indicator-Card Apparatus.

Draper of the engine lab. has been using a circuit I showed him which allows a very small electrical impulse to control considerable energy and make a record on carbon paper. He has experienced considerable trouble because of the temperature of the tube. The device only works over a definate range of temperatures which is rather small. I showed him some circuits on May 22 which I hope will over come this difficulty.





May 29, 1931. Indicator circuit.
to be tried.

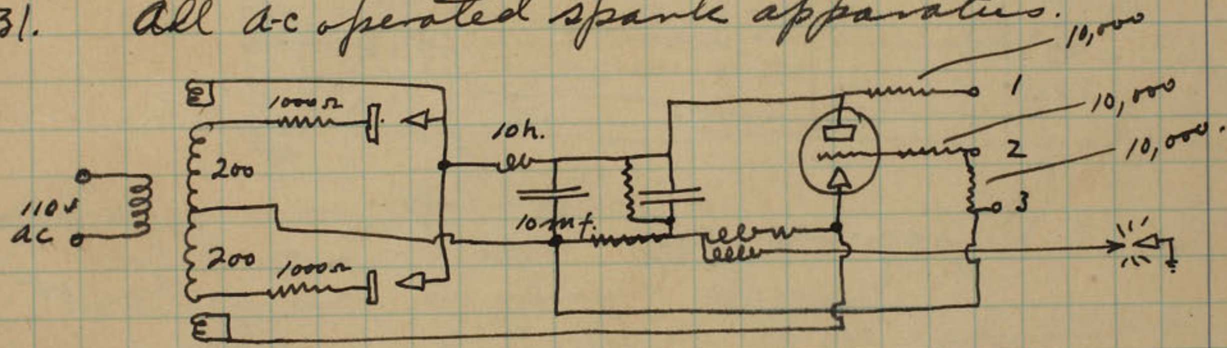


June 2. tried and works ok. with an FG-17.
" " " " " an FG-33

this circuit Burns more than if R2 is used

see page 120 for details.

May 31. All a-c operated spark apparatus.



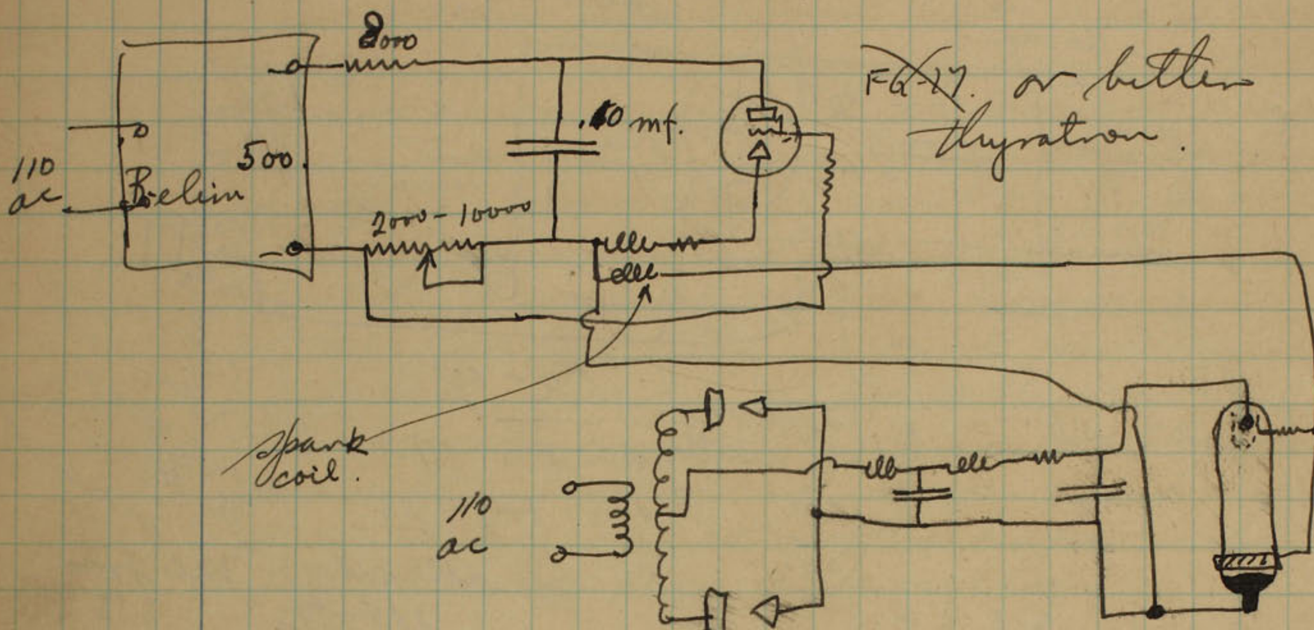
To get spark on the close connect 1 and 2. for flash

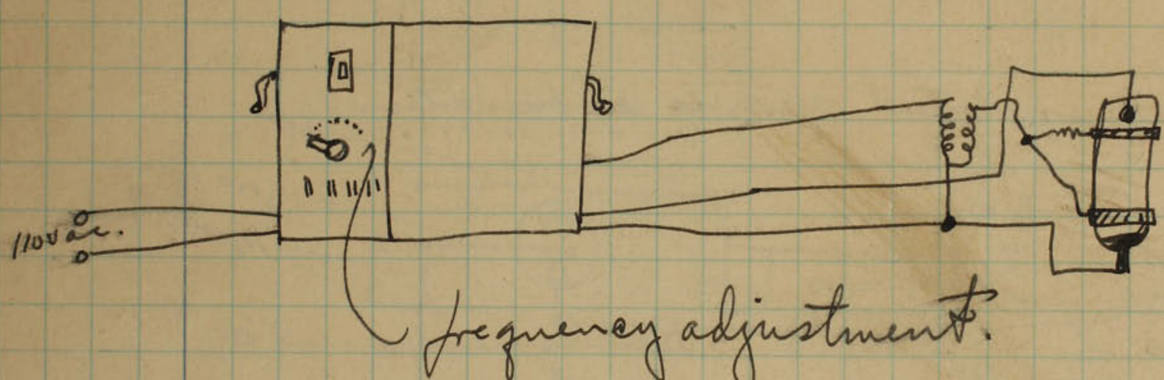
" " " " open connect 1-2 permanently.
open 2-3 to get flash.

May 29. 1931.
H. E. Edgerton

Stroboscope.

Also see notebook 3. on synchronous machines



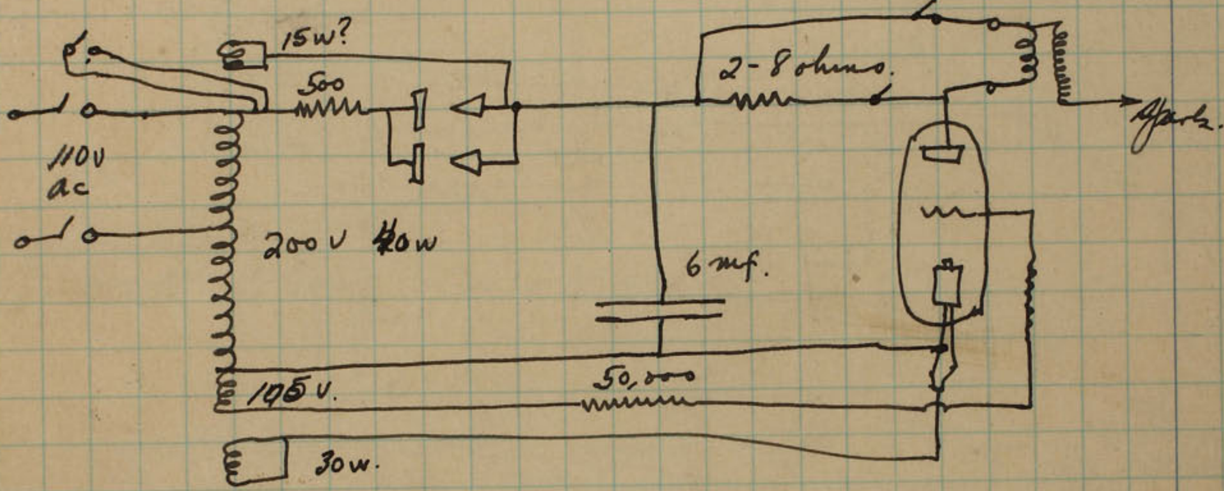


Cooper Hewitt
Lamp or
other mercury
tube. Pool
of mercury at the
bottom.

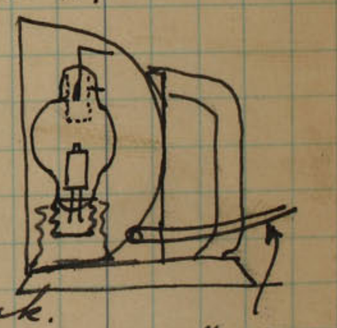
Stroboscope

May 31 1931
H. E. Edgerton.

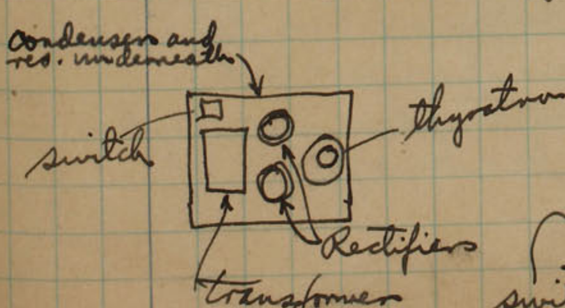
A stroboscope for visual work will be a very convenient piece of apparatus. The one designed below is to be a cheaply made outfit which will be operated from any a-c 110 volt circuit (from 25 to 133 cycles per second). It will give sufficient light for observation ~~but~~ and may be good for shadow photography.

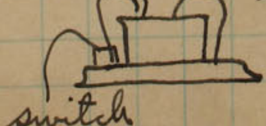


1- transformer 100 watts.
1- condenser 6 mf. 300v d-c.
1- resistance 500 ohms 200 ma.
1- resistance 2-8 ohms. 200 ma. adjustable.
1- resistance 50,000 ohms.
2- sockets for rectifiers.



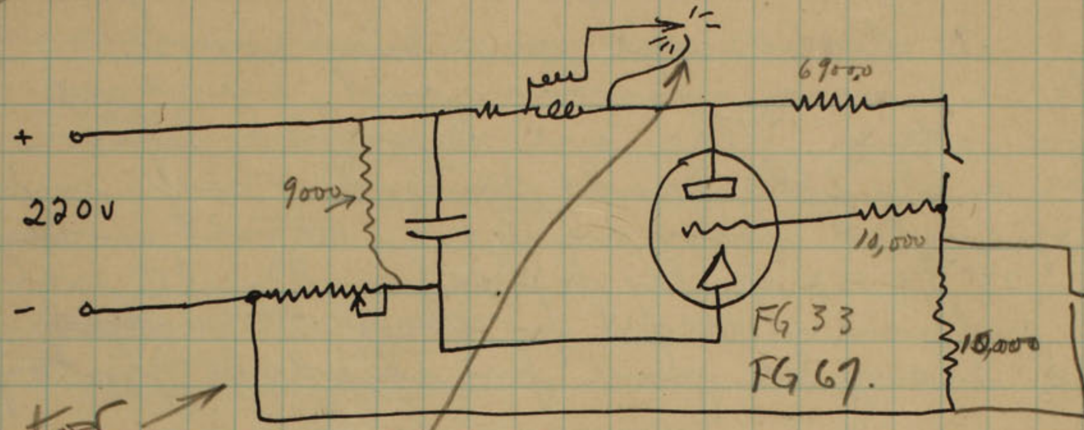
Tubes 1- special thyratron. 100 amp. peak.
2- rectifiers.



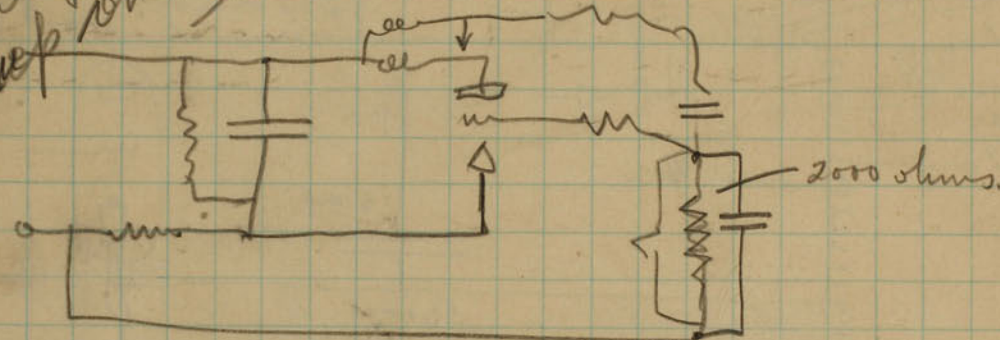


15 ft
An extension cord with a socket and a shade so that the light can be directed without carrying around the entire outfit.

June 2 1931
H. E. Edgerton



Good oscillator
A neon tube was put on the output and it lighted up ok.



This was seen in operation by
Carl Neitzert
Henry Lawrence

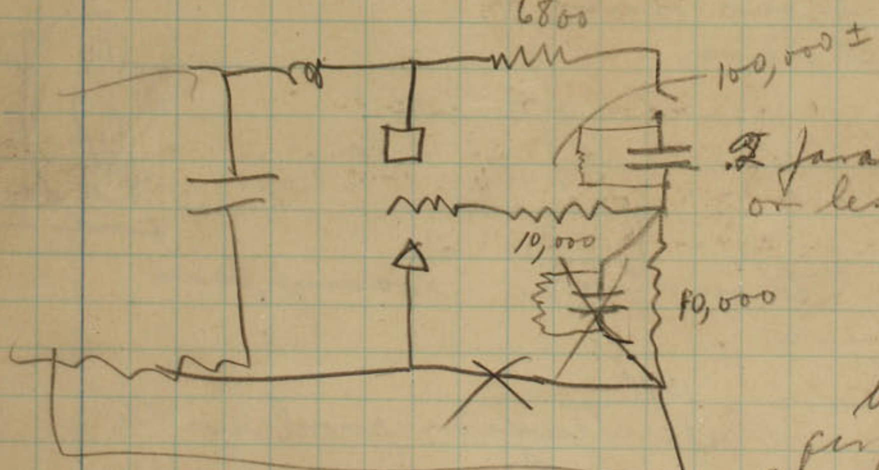
$RC = .0001$ sec

$R = 2000$

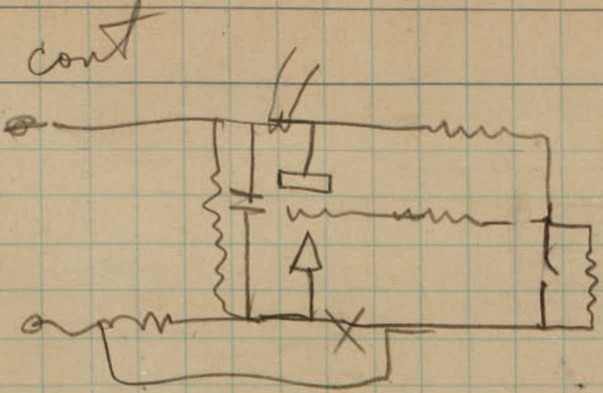
$C = \frac{.0001}{2000} = \frac{10^{-4}}{2 \times 10^{3}} = 5 \times 10^{-7}$

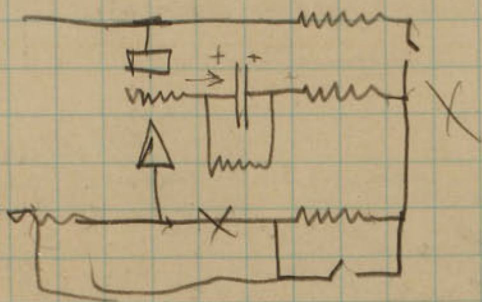
$= .5 \times 10^{-6}$

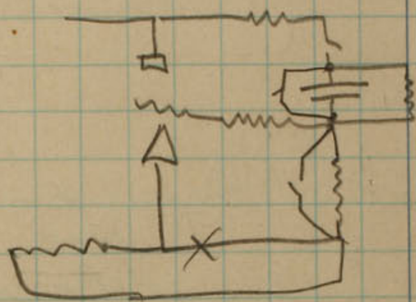
$= .5$ farad.



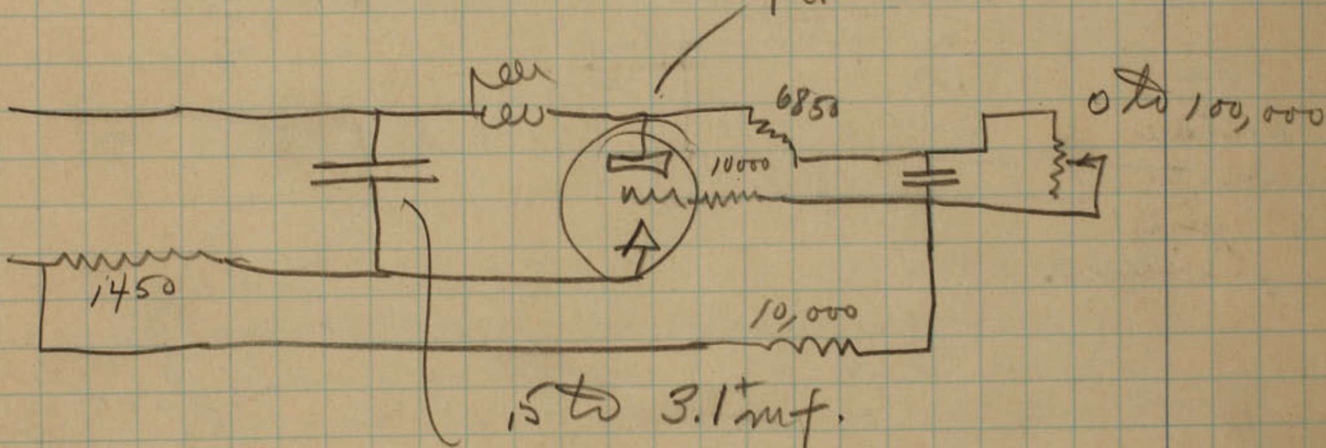
Condenser to cut out buzz after the circuit is made.
Ok but the charge must leak off.
Works fine.





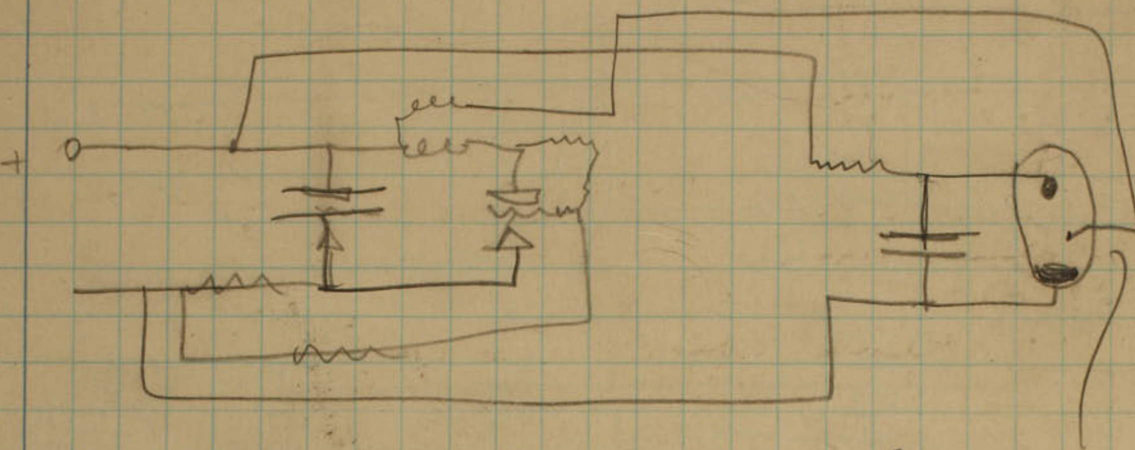


Good osc. circuit



3.1 mf charged to about 300 v
and discharged through the FG 67 gives
about a 1/2 inch spark.

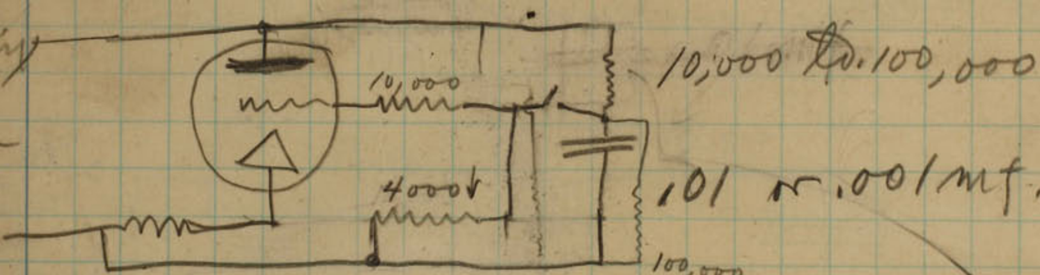
cont.



Mercury Pool tube.

Not very satisfactory operation of this was obtained. A special type of pool tube is needed.

Scheme for turning on the thyratron with a make.



$RC = .0001 \text{ sec}$

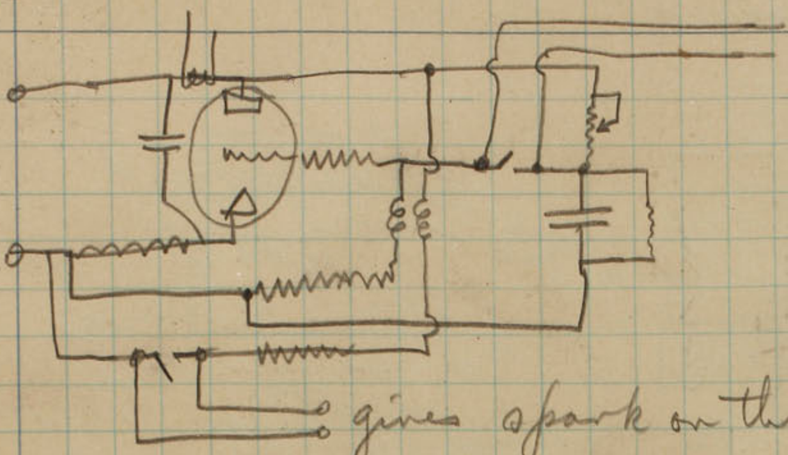
$R = \frac{.0001}{.1 \times 10^{-6}} = 1 \times 10^{-4} \times 10^{+9} =$ ~~1000×10^{-6} ohms~~. 10^{00} ohms.

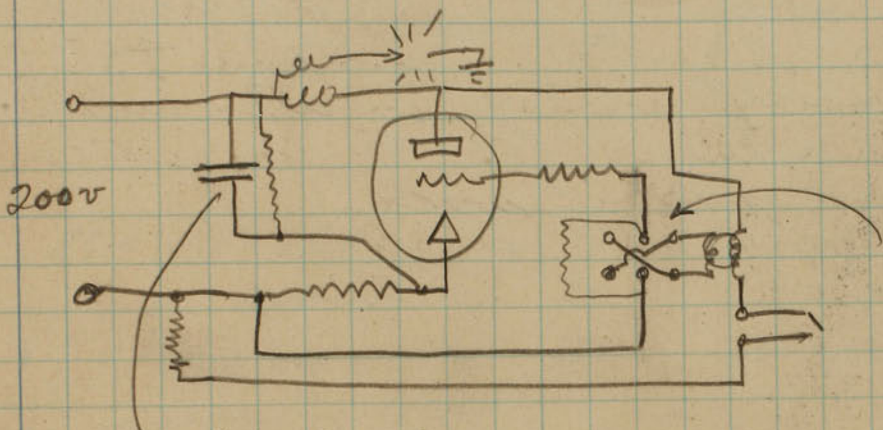
ohms

$10^{00} \times .1 \times 10^{-6} = .00,0001.$

Adjust resistances so that the discharge is out both when the switch is open or closed. The tube will flash when the switch is closed.

cont





This looks good!!!

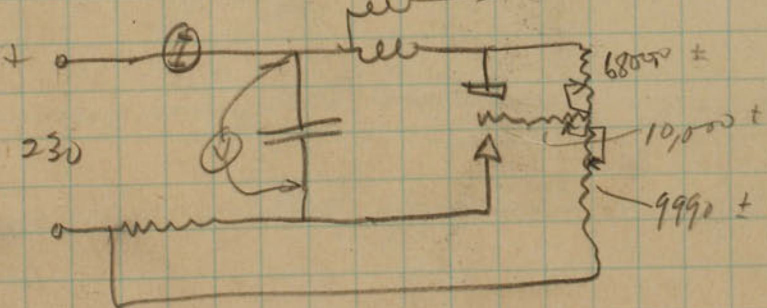
Reversing switch to change from on to off for spark.

.5 to 2 mf.

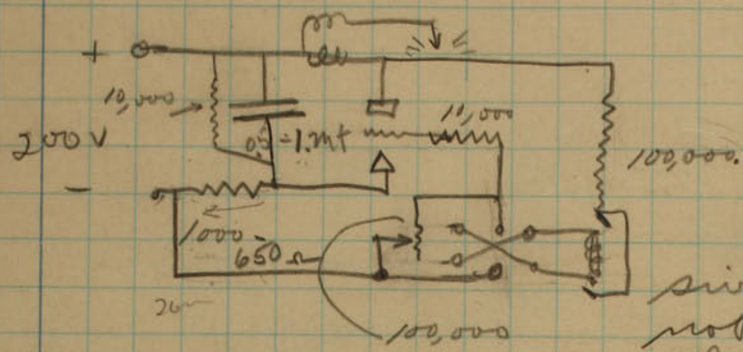
1000 to 500 ohms.

June 3 1931.

I tried the circuit shown on the top of page 120 working as an oscillator up to an input of .16 amp with an FG-67 tube as the valve. Refuses to oscillate above 1.08 amps as input



June 3, 1931. Trip circuit $4 \times 4 = 16$



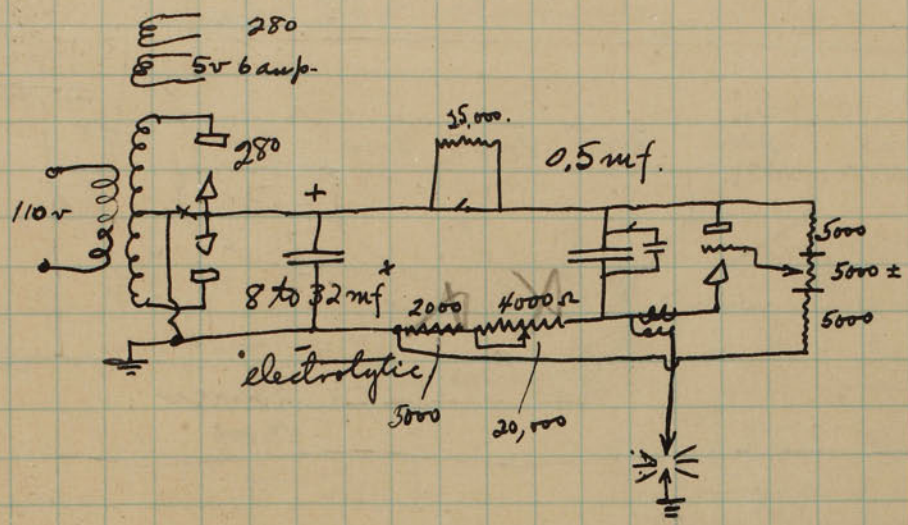
This circuit works fine.

The reversing switch is really not needed?!! When contact is broken or made apparently their is sufficient variation of contact resistance to give enough voltage in either direction to trip the tube. Eddie Taylor came over and saw it work.

$\frac{.5}{1000}$

.0001 sec.

June 17, 1931. All A-C Thyratron Oscillator.



$RC = 0.5 \times 2000 \times 10^{-6}$ sec to $0.5 \times 6000 \times 10^{-6}$ sec.

1.000×10^{-3} .. to 3×10^{-3} sec.

$\frac{1}{T} = f = 1000$ to ~~330~~ 330 cycles per sec.

Increase fixed resistance to 5000 ohms.

" variable resistance to 20,000 "

$\frac{1}{RC} = \frac{10^6}{5000 \times .5 \times} = \frac{10^3}{2.5} =$ 400 cycles sec.

$\frac{10^6}{25,000 \times .5} =$ 79 cycles/sec.

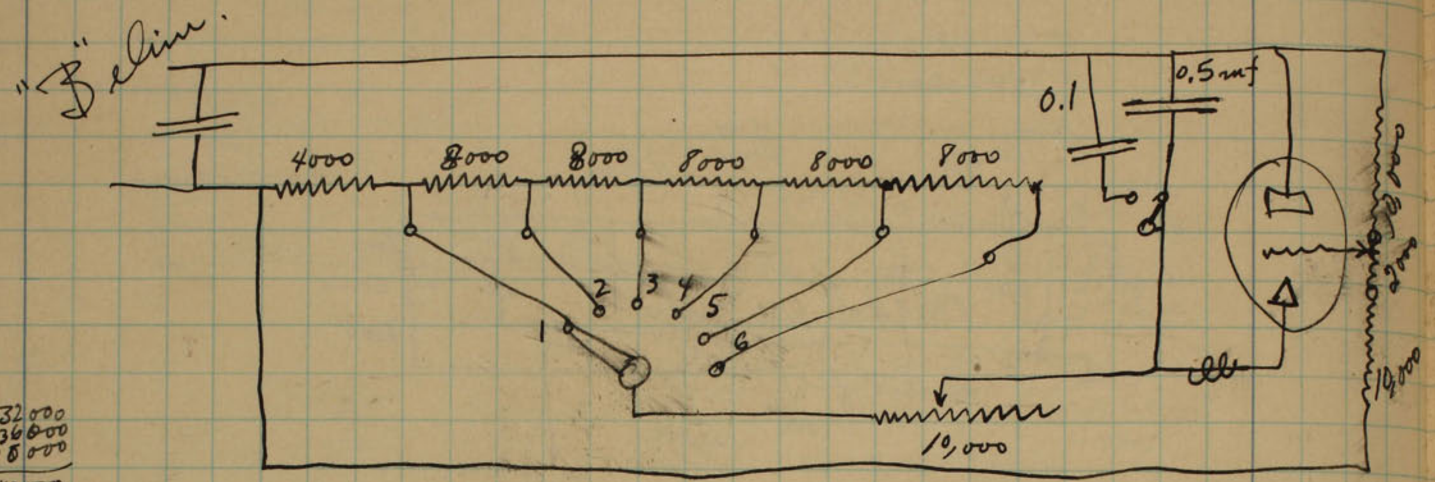
With a capacity of ~~0.05 mf.~~ 5.0 mf.

$f = \frac{1}{RC} =$ 40. to 7.9 cycles /sec.

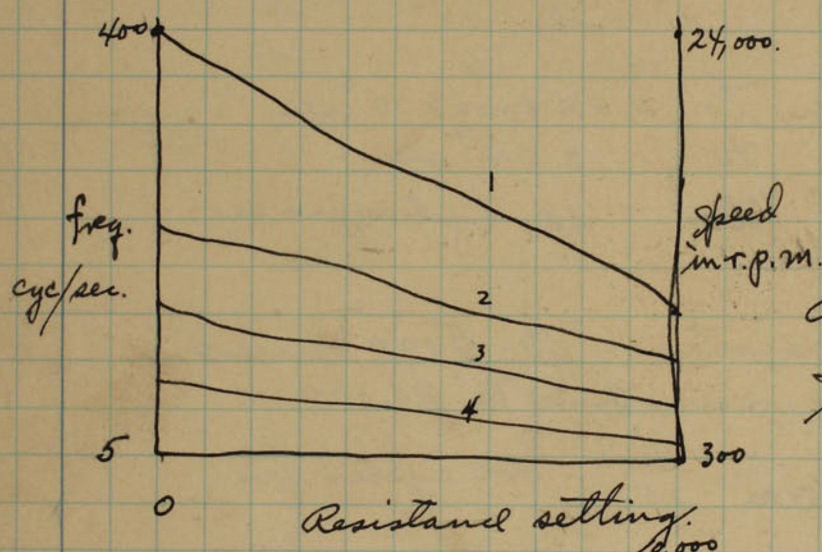
Energy may not be enough? $7.9 \times 60 = 480.$ r.p.m.

Insert a fixed resistance of ~~50~~ 25,000. 39.5 cyc./sec.

Thyratron vibrator



32000
36000
18000
42000.



$$\frac{10^6}{14000 \cdot .5} = \frac{200}{14} = 14.3.$$

calibration chart.

two charts one for each capacity.

$\frac{400}{60}$
24000

$\frac{400^2}{.4\,???} = \frac{16}{4} = 40.$ watts.

$400 \cdot \frac{8000}{12000} = 260 \quad 12.5$

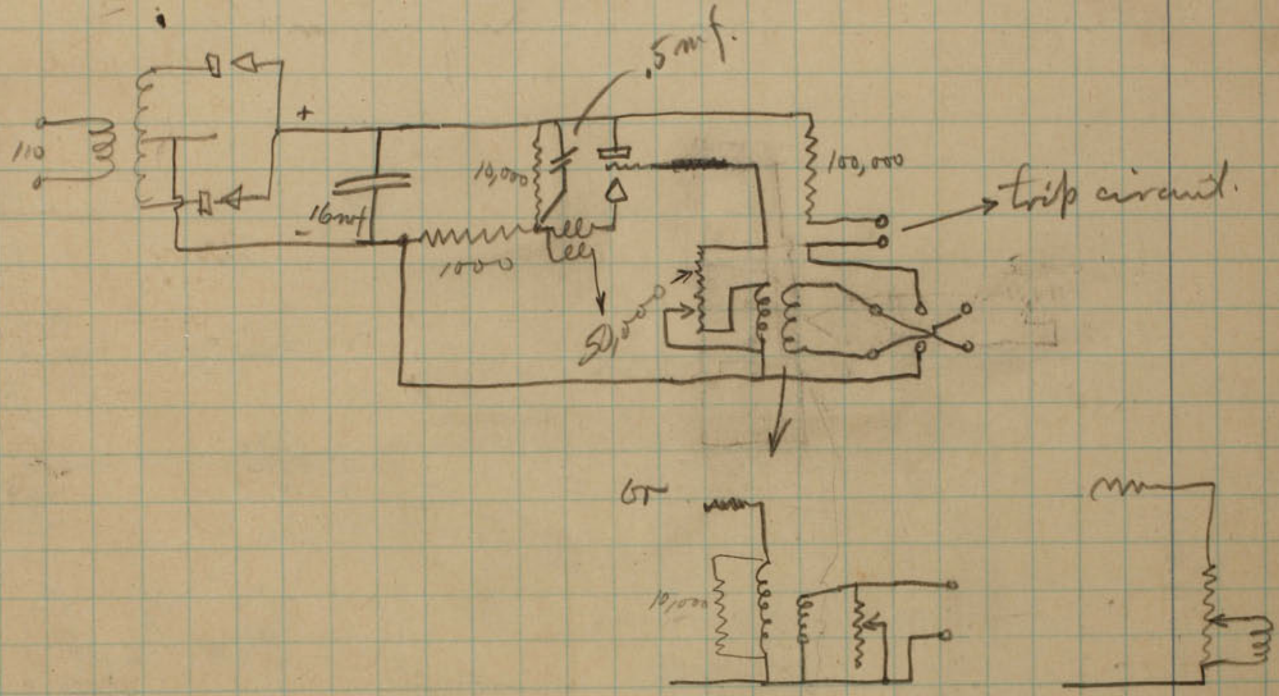
1 –	4000 –	50 watts.
1 –	8000 –	25 watt
1 –	8000 –	5 watt
4 –	8000	2 "

1 – 10,000 Ω variable 100 ma. at one end

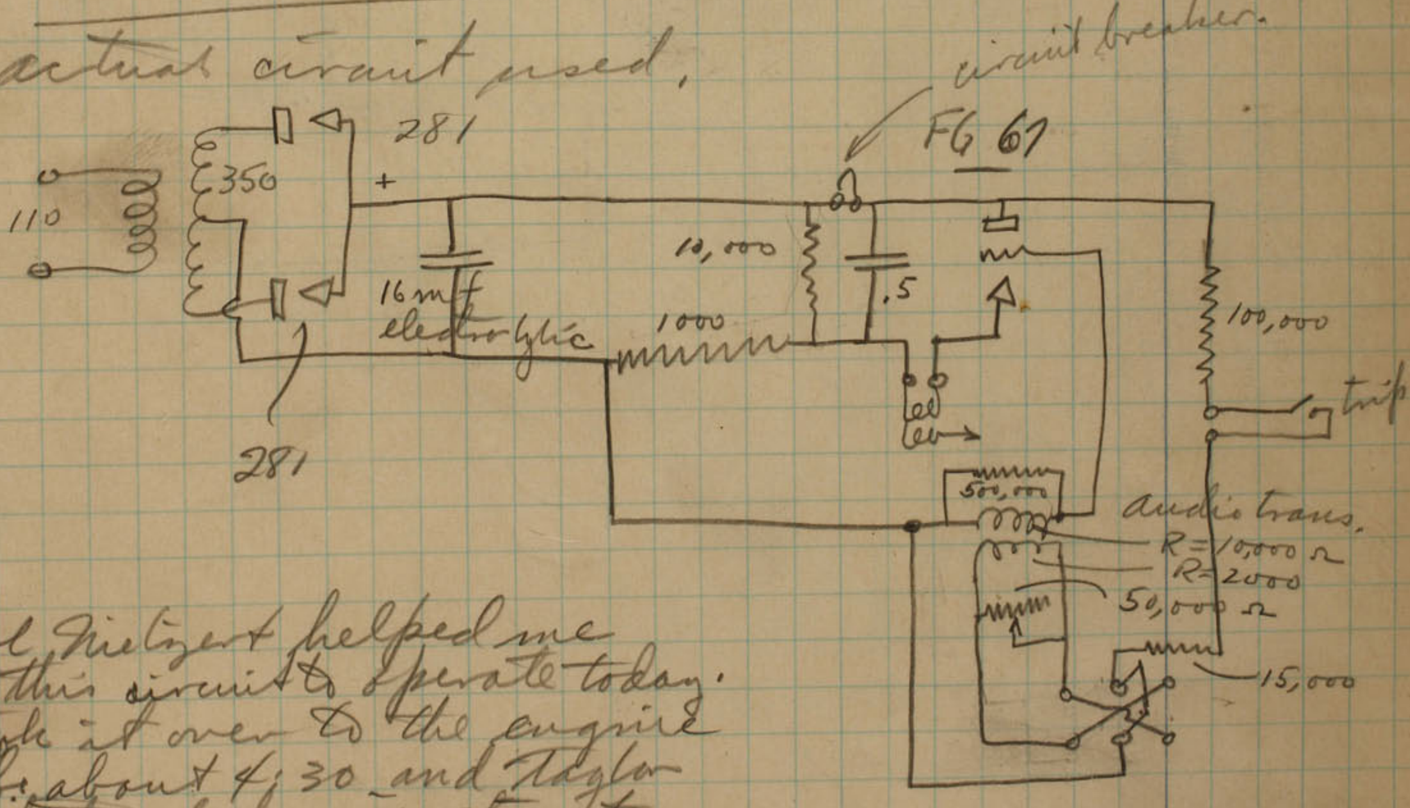
.01

June 19, 1931.

Purchased supplies for the indicator apparatus for Engine lab. yesterday.

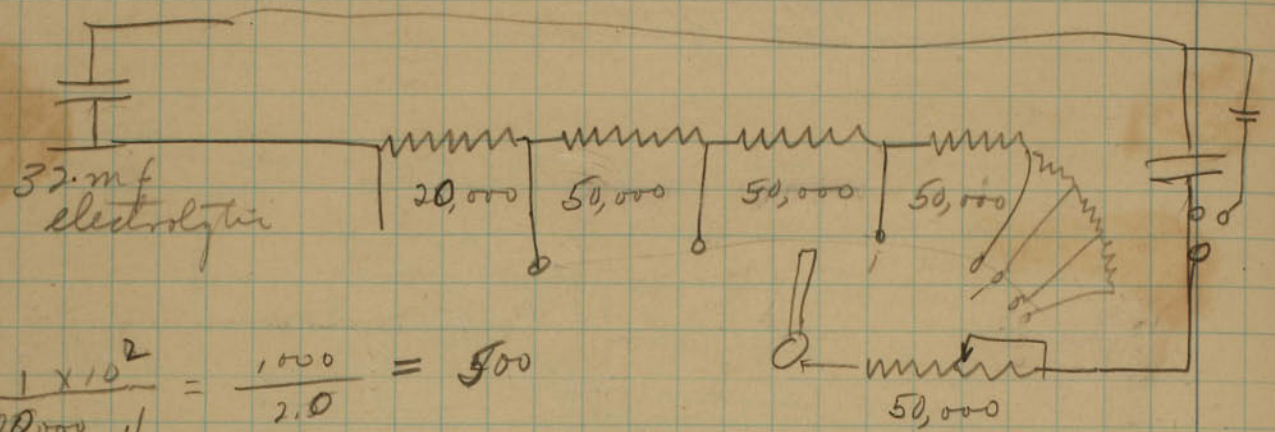


actual circuit used.



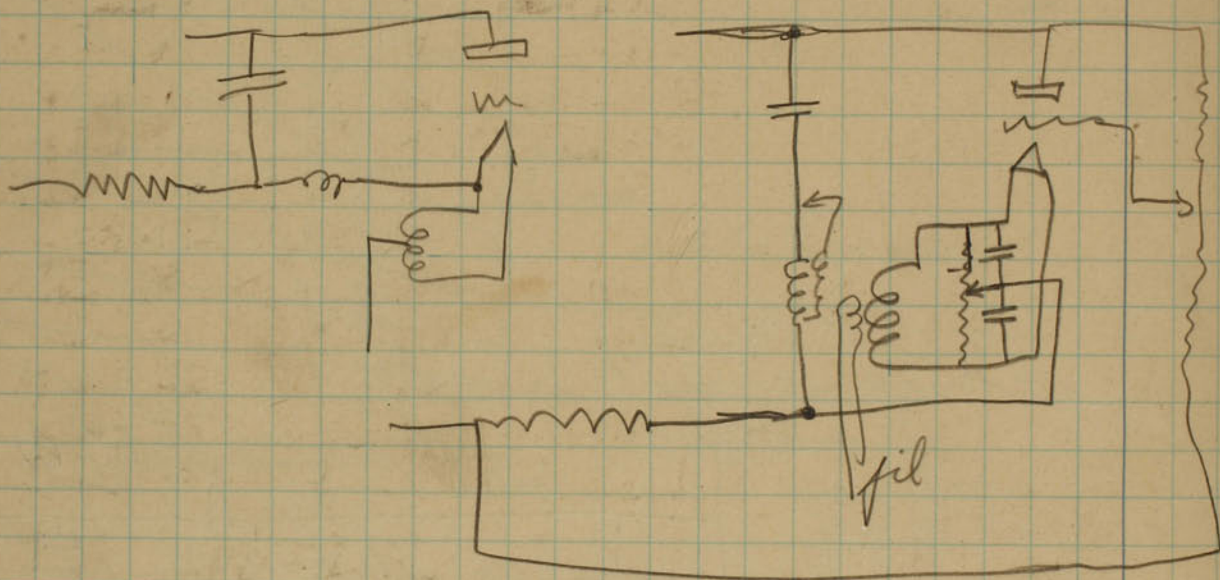
Carl Mietzger helped me get this circuit to operate today. I took it over to the engine lab. about 4:30 and Taylor and two lab. assistants saw it work. We did not get a chance to take any indicator cards.

cont p 126.

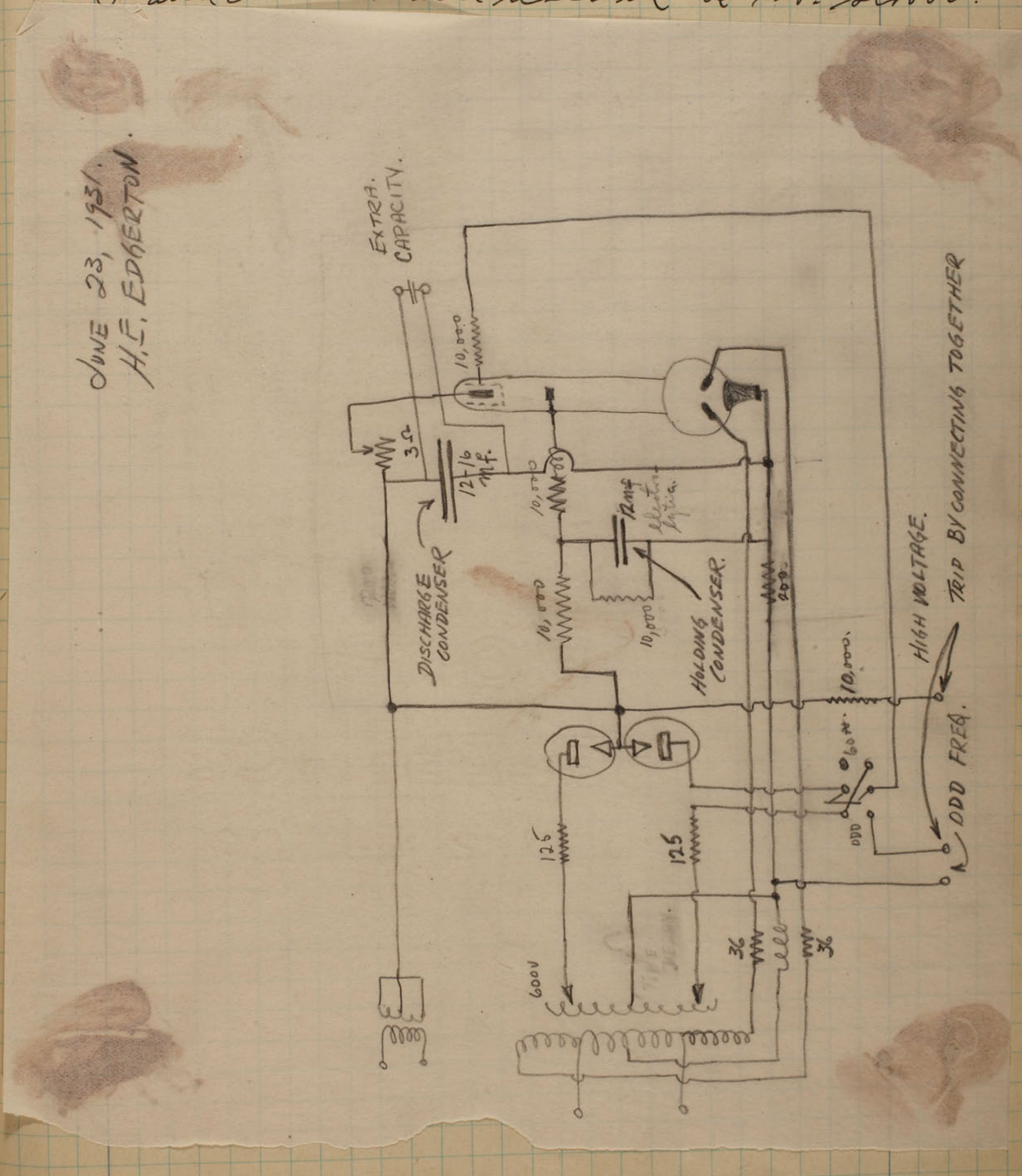


$$\frac{1 \times 10^2}{20,000 \quad .1} = \frac{1000}{2.0} = 500$$

$$\frac{10^6}{R \quad .5} = 5. \qquad R = \frac{10^6}{3 \times .5} = \frac{10^6}{2.5} = 1400,000. \text{ ohms.}$$



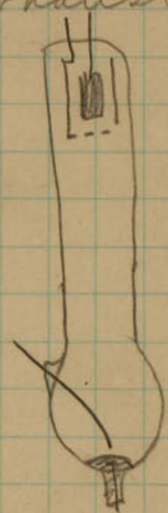
June 23 1931. Suggested modifications of the circuit shown by McClure and Stander and used in the lab. strobo.



June 24
24.

Mr. C. G. Smith of the Raytheon Inc was over and saw the lab. stroboscope which was built by Stander & McClure. I talked with him about the arrangement of p 112 wherein a high voltage starts the spot for each flash. He suggested that a filament placed close above the pool might help to establish a mercury spot because of the increase in vapor pressure. I plan to try this out.

I spent sat, mon, and tuesday exhausting a tube of the shape shown. No bombarder was available to drive all the gas out of the anode and grid and as a result the tube has some gas in it which gives a faint red glow when excited by the sparks.



The tickler wire does not actuate the tube very consistantly. I tried a piece of tinfoil around the bottom and this seemed to work OK.

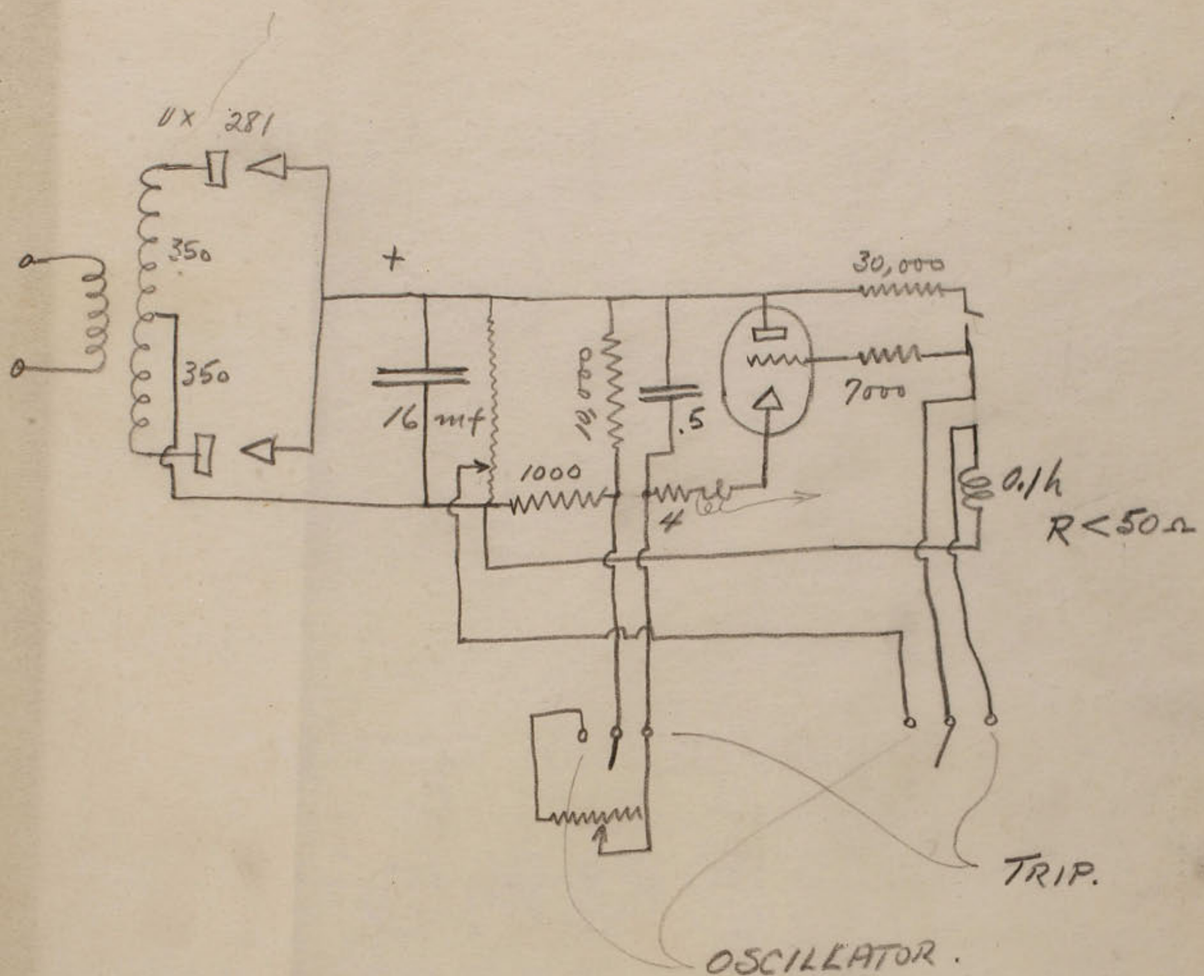
A spark from a spark coil which resulted from a condenser discharge through a FG 67 thyratron was used to trip the tube by starting a spot.

June 25

I also tried the sparks on a 22 inch standard ~~ther~~ Cooper Hewitt lamp and it worked alright.

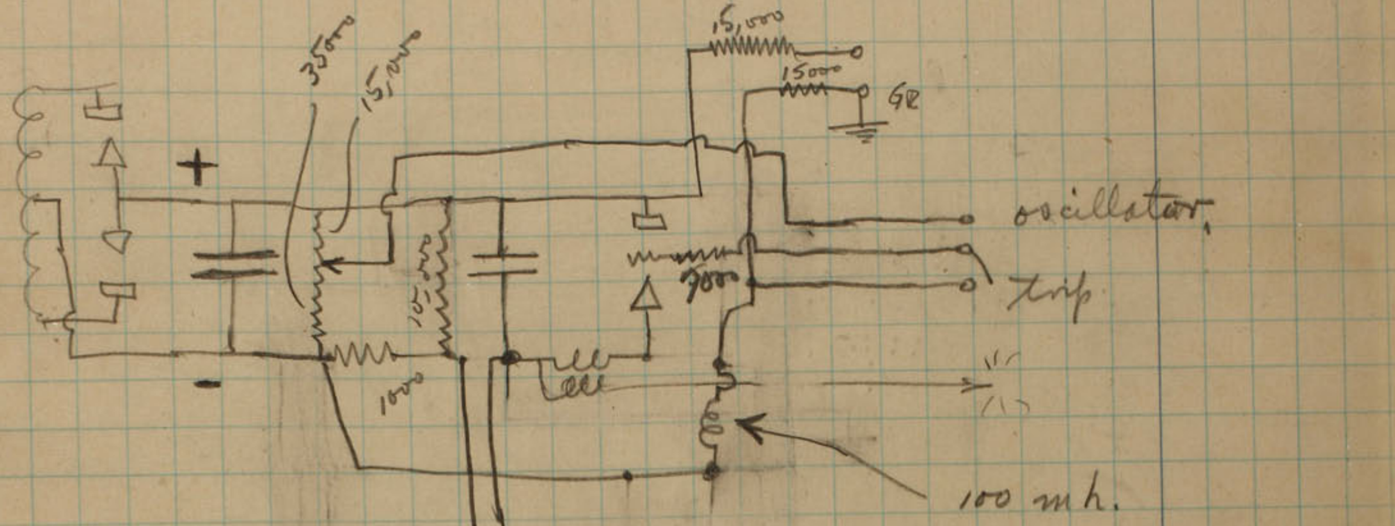
I still need to test these circuits for flicker by observing a synchronous motor.

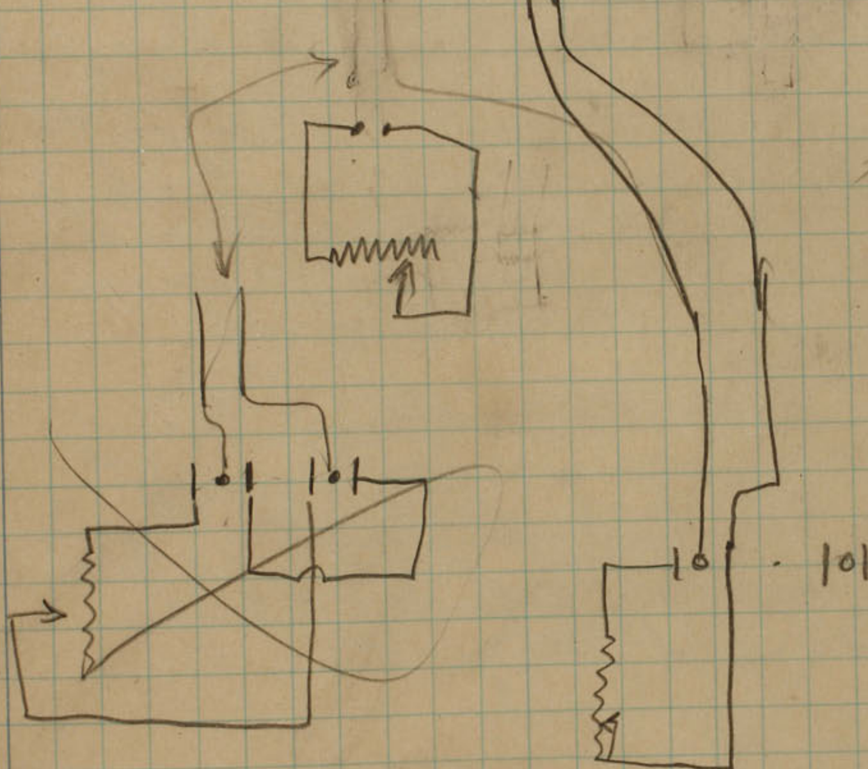
Appears to be O.K. There was a small variation which was in phase with the noise from the motor which must have been due to hunting.


UX 281
350
350
+
30,000
7000
16 mf
10,000
.5
1000
4
0.1h
R<50Ω
TRIP.
OSCILLATOR.

June 25

cont p 127.





$RC = 1,000 \times .5 \times 10^{-6}$

$.5 \; 10^{-3} = .0005$ sec

500 μs.

$\frac{L}{R} = \frac{.1}{10^5} = 1. \times 10^{-6}$ sec.

Inductance works fine for the trip circuit.

Oscillator part fails to work for some reason.

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

$1 = 60 RC$

$1 = 30 \times 10^{-6} R$

$\frac{1}{.3 \times 10^{-4}} = R$

$10 \times 10^4 = R$

100,000.

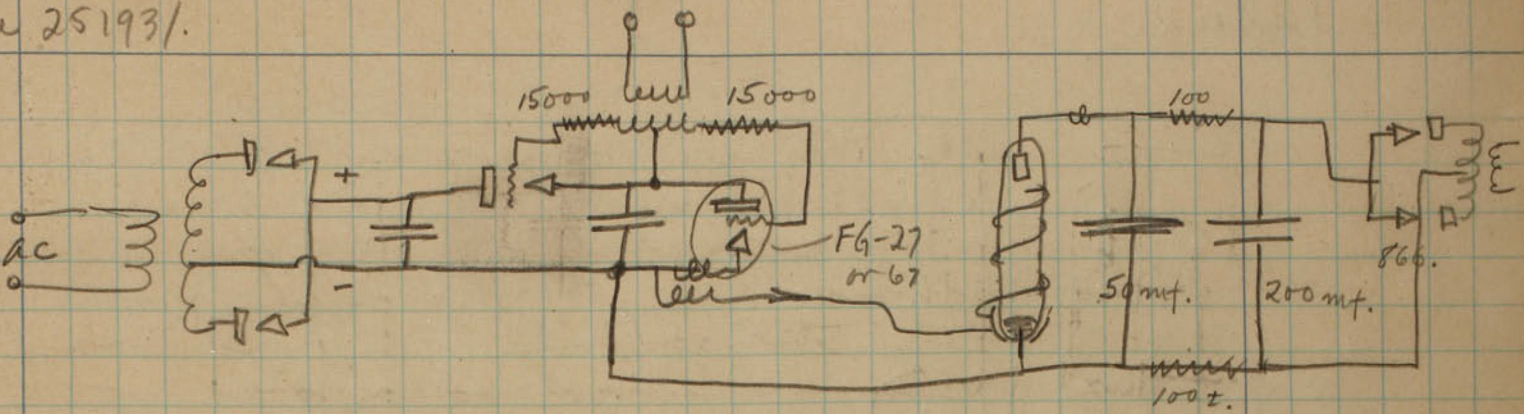
June 25 1931

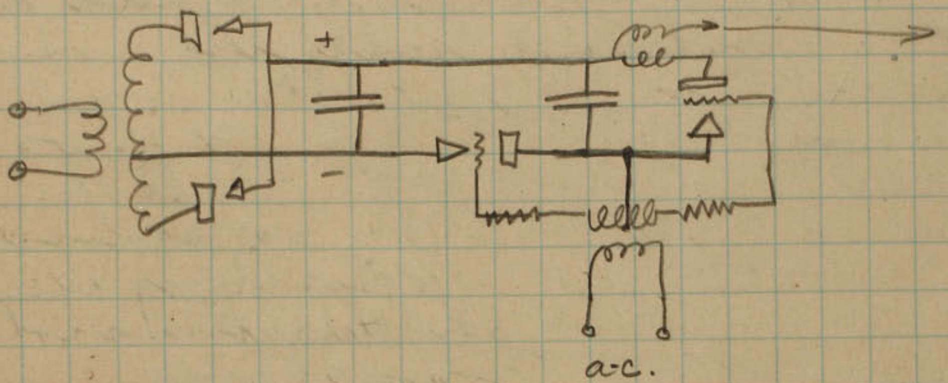
My experiments of today are very encouraging. We can use for stroboscope tubes simple tubes with an anode and cathode instead of the complicated thyratrons that we have used in most of the experiments to date. Our laboratory stroboscope now has a special tube that has seven seals and it is expensive and dangerous to move and use.

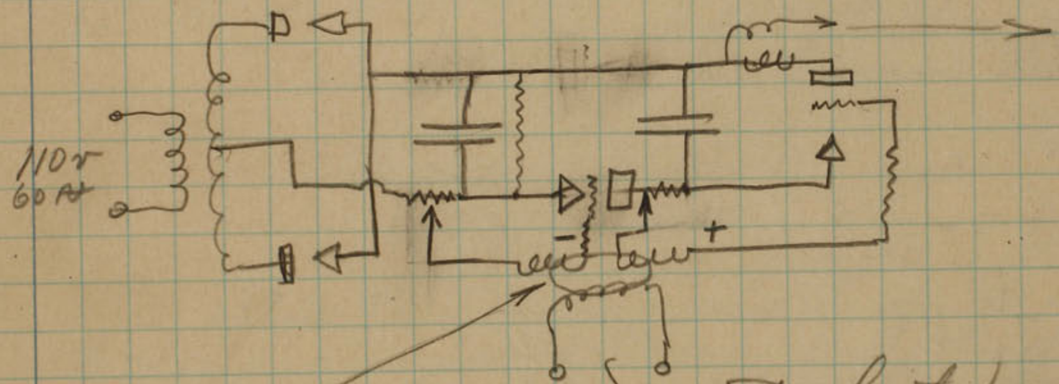
A small thyratron will act as a switch which will trip a large tube from the outside by means of a condenser plate around the cathode and external grid.

We tried to do this same thing several years ago with a cooper Hewitt lamp but the experiment was a failure because of the difficulty of starting the spot. The small thyratron does the trick.

June 25 1931.



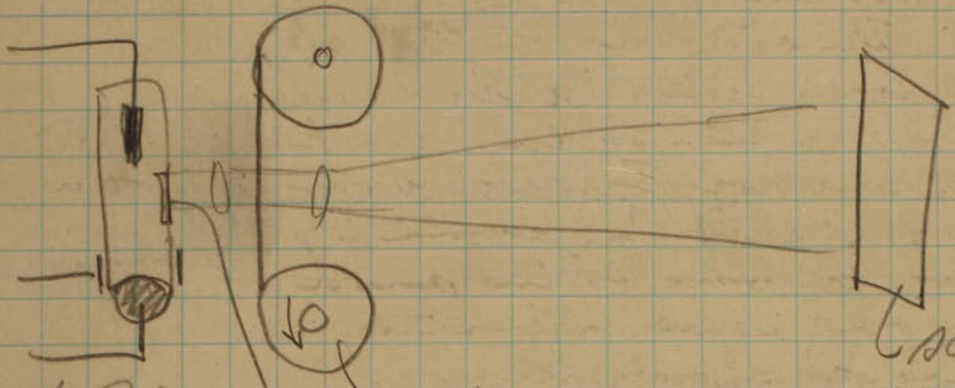




Allows current to flow when the thyratron grid is negative and thus charges up the condenser.

To beat freq oscillator or other a-c source to ~~give~~ control stroboscopic light.

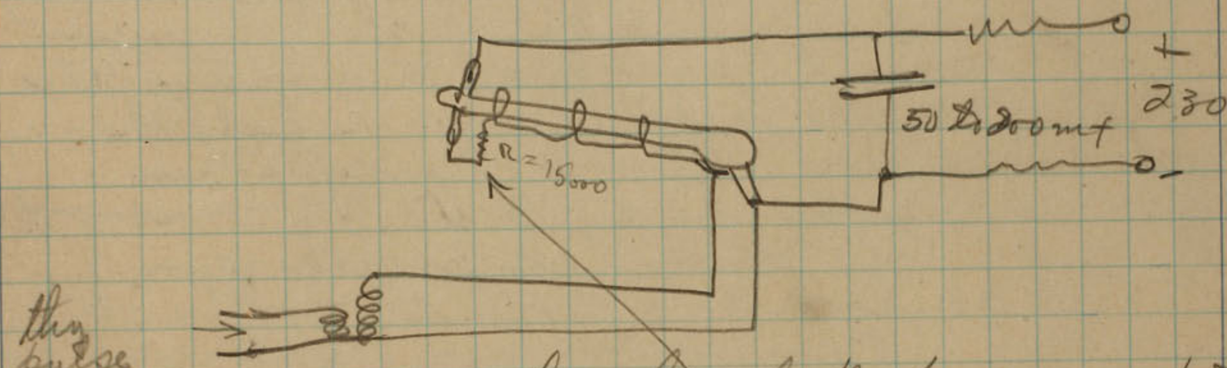
June 26 1931



July 1. 1931 Film does not pass U.V. ?

June 26, 1931

Used circuit of p 131 as an oscillator. The output of the spark coil was connected to the condenser starting connection of the Cooper Hewitt lamp. A fine wire was wound around the lamp up to the anode and connected to one of the anodes. The other anode was connected to a condenser as shown below.

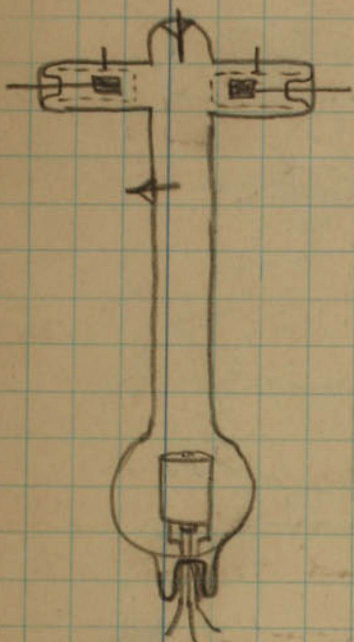


The light flickers somewhat if the anode here is disconnected.

I took the arrangement of P 131 over to the engine laboratory and Prof. E. Taylor tried it out. It did not give an indication on the break for some reason. The contacts may be bad or the circuit somewhat slower than estimated. The oscillator part worked great and gave a lot of light from a neon tube.

The tube from Dr A.W. Hull of the G.E. Company arrived. It looks like a dandy.

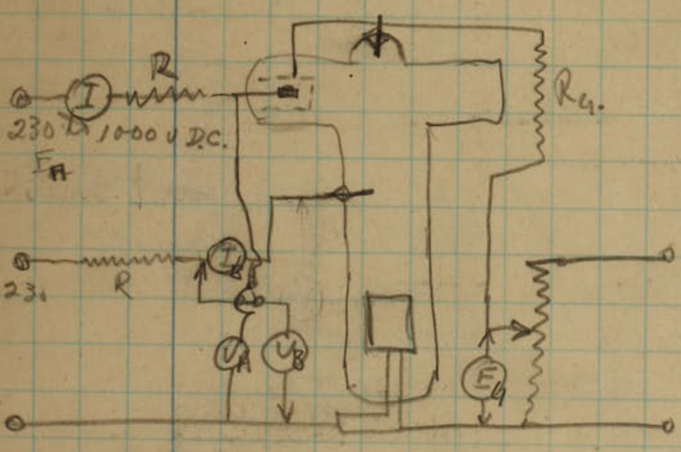
June 27 1931



The special thyratron that Dr. A.W. Hull sent has a cathode about 1 3/4 inches in diameter. It is of the fin type, protected by the can against excessive heat radiation.

The emitting surfaces do not appear to be coated with oxide. The metal appears clean or only slightly tarnished. I connected up the filament and ran it at 5 volts. The surfaces became a dull cherry red. About 15 amperes was passed from one of the anodes with an arc drop of 32 volts. With 5 amps the arc drop was 36 v.

June 28 1931. Tests to be made.



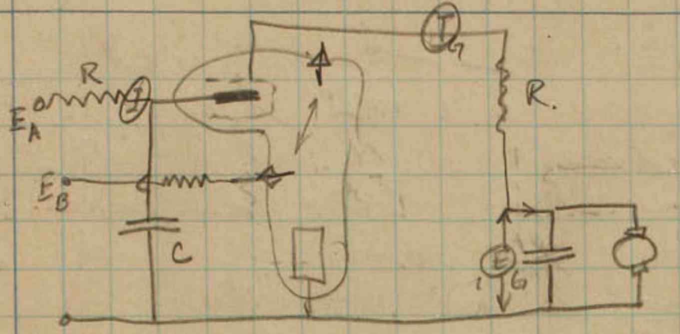
I_B = constant
1, 10, 100, 1000 ma.

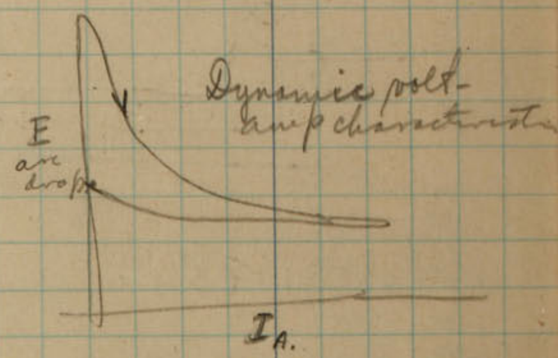
R = such as to allow 5 amp to flow.

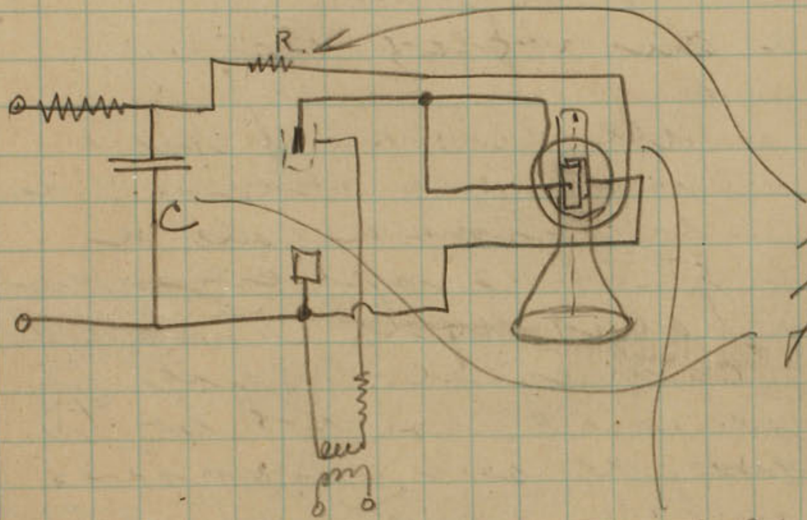
E_G ~ E_A for arc to strike.

Put condenser across anode to cathode to see if the critical condition is the same.

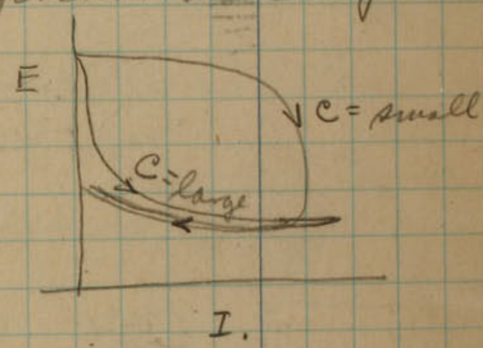
Determine the limits of oscillation.



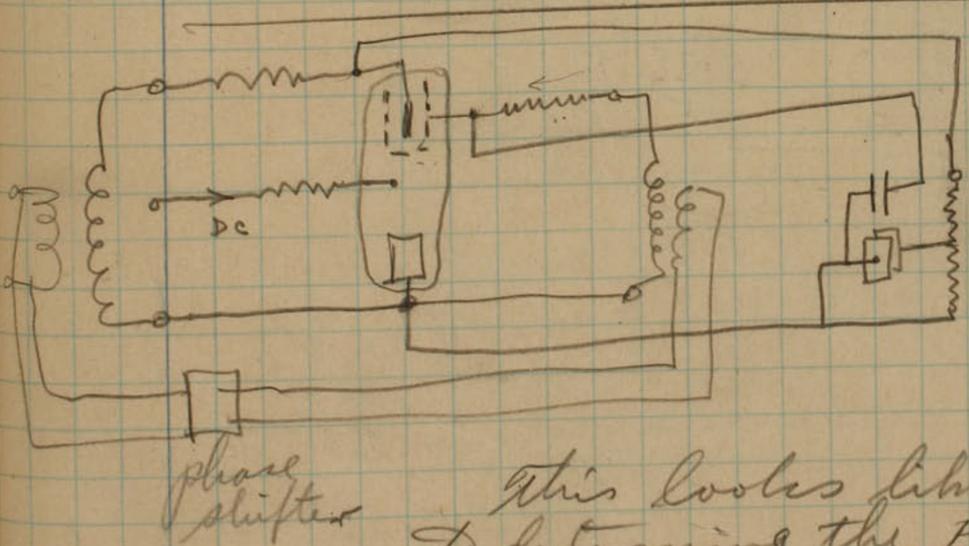


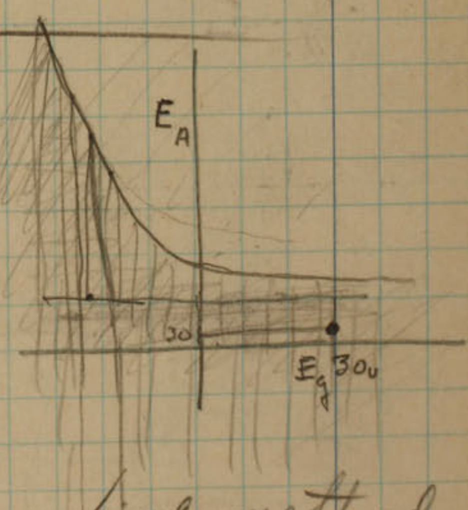


keep R constant and obtain characteristics for different values of C

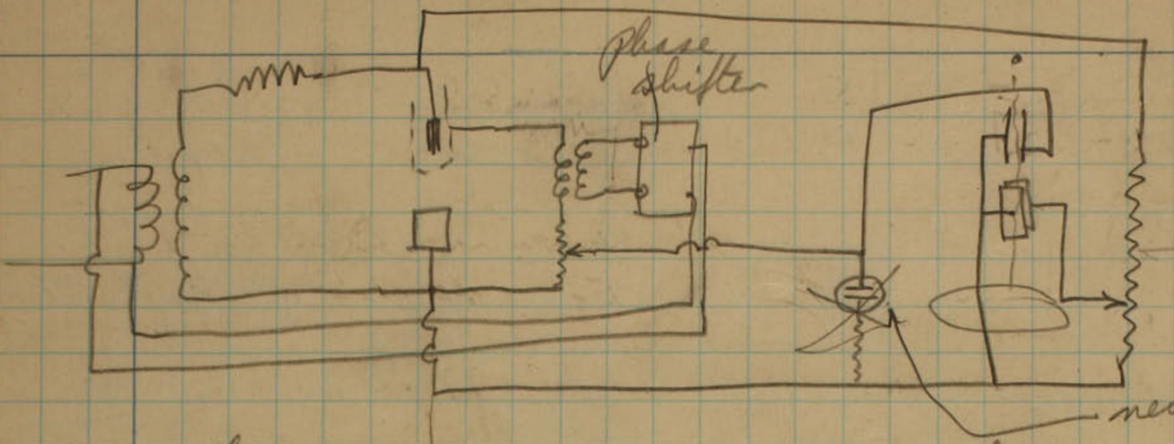


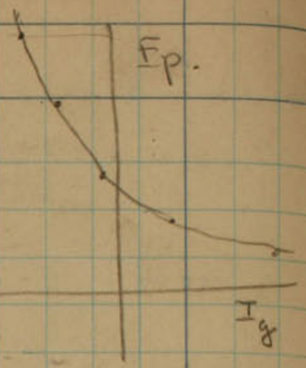
magnetic field deflects beam prop. to the current.



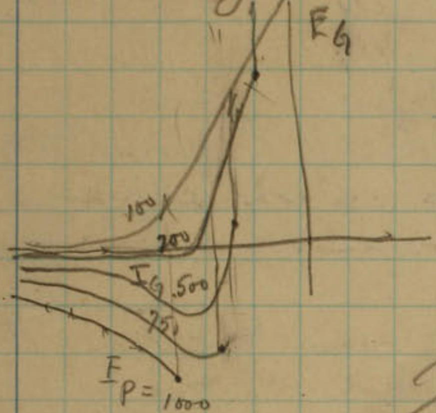


This looks like a fine method to determine the $E_A - E_g$ characteristics of thyratrons. It should be fast and accurate ~~since it is a~~ and is a dynamic determination

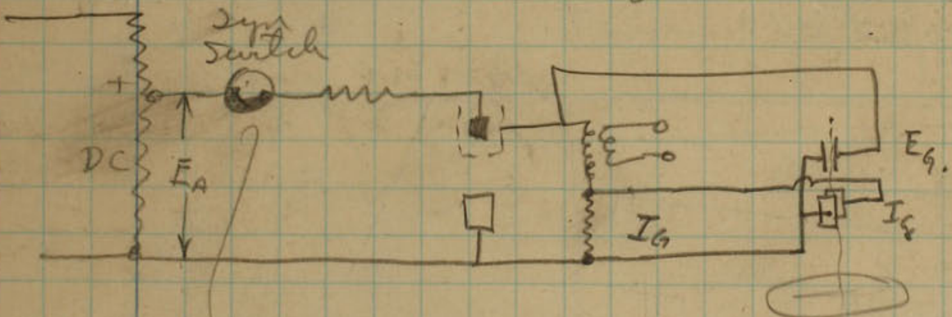




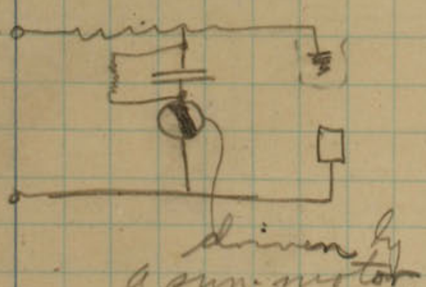
this gives a curve of $E_p - I_g$



Use dc on the plate with condenser and resistance as a stroboscope circuit so that it will extinguish each cycle. another scheme would be to use a synchronous switch to disconnect the plate circuit.

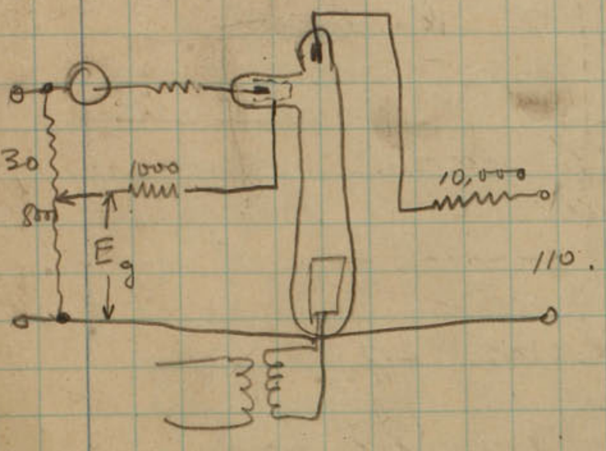


or



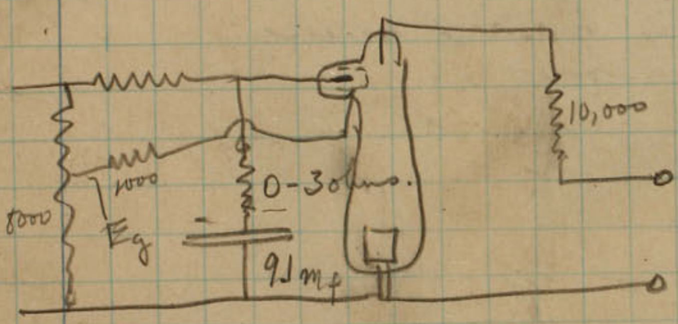
June 29 1931

	#873	#30041
Filament when hot	5.1 v.	27.4 amps.



Condition to start 2 amps.
E_g = 46 volts R_g = 1000 Ω.

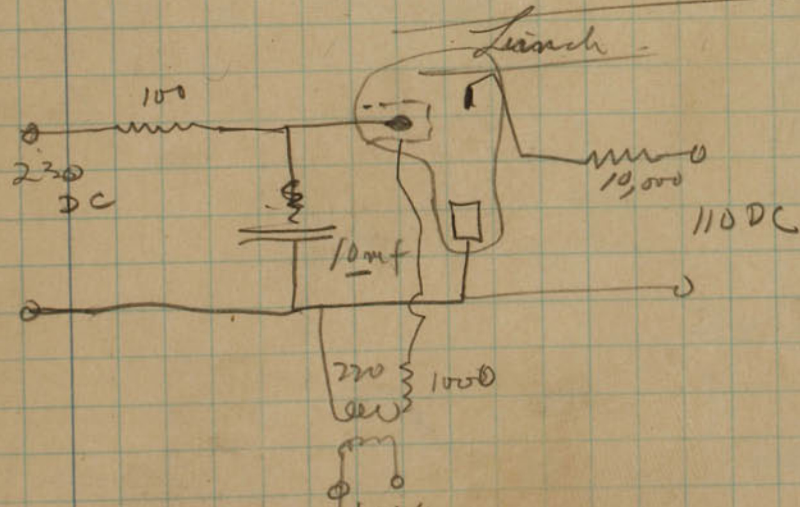
94.5.	11,000	
101.	11,00	3.95 I
109.	11,000	2.00
111	11,000	3.95.
117	11,000	2.00



oscillates at a high frequency 3000 or 5000 cyc/sec.

Reduce R in series with C reduces freq.

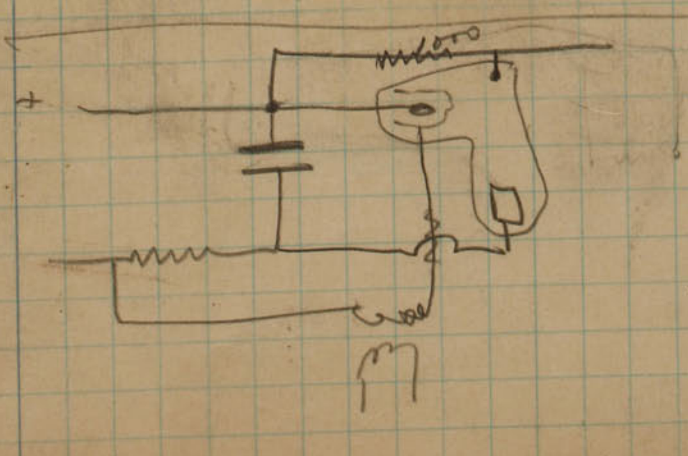
Reduce E_g reduces freq.



works fine
freq of tracers 54

$$\frac{\times 60}{3240.}$$

(27 × 2) × 60 = 3240 cycles/sec.



June 30 1931

Spent all day getting thyratron on the exhaust system in 10-385. Dr Bush gave several suggestions regarding cleaning the tube and mercury. C. P. mercury was used today. The tube was washed with chromic acid, distilled water and alcohol. An oven must be built tomorrow.

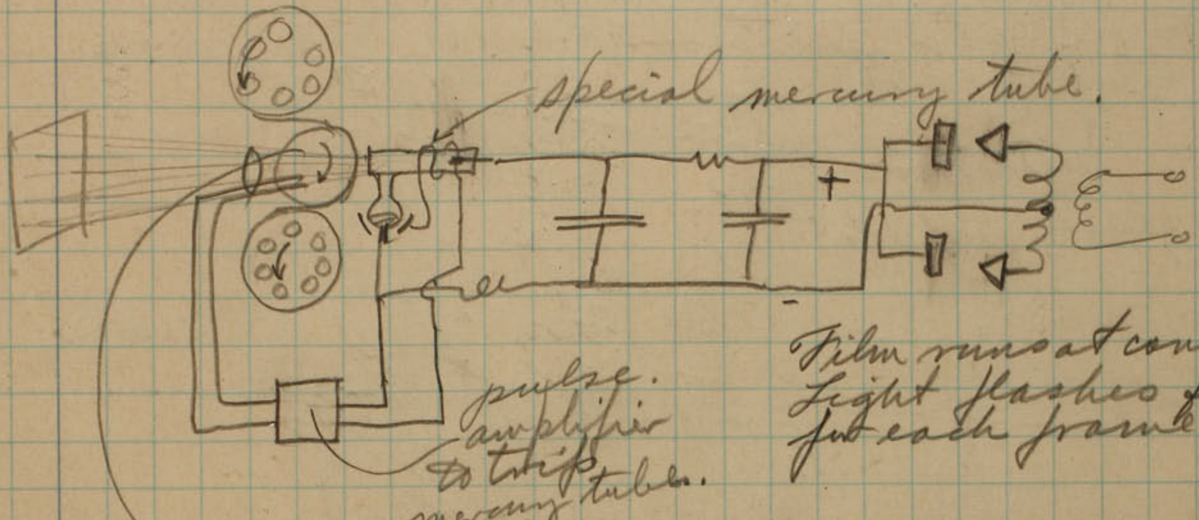
July 1 1930 Exhausted the tube and sealed off at 6 pm.
2 1930 Tried tube in circuit and it works ok. Cleaned the mercury out of an old broken tube and will try to fix it up tomorrow. Practiced making tungsten to pyrex seals.

July 3 1931. Worked in office and hunted for a house

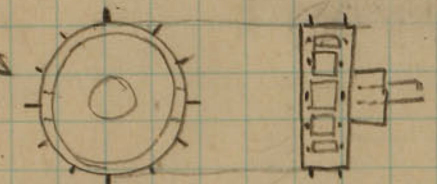
July 5 1931

H E Edgerton.

Moving Picture Projector. (Stroboscopic).



Film runs at continuous speed.
Light flashes for about 20 μs for each frame.



12 frame sprocket.
24 frames per second.
2 rev per sec
or 60×2 = 120 r.p.m.

33⅓

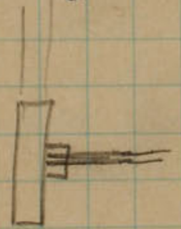
$33\frac{1}{3}\overline{)1440}$ 4 ... 132 ... 120

$3\overline{)1440}$ 480 ... 12 ... 24

$\frac{120}{3}$ = 40 to 1 gear to sound.

.5 in × 12 6 inch $\frac{6}{\pi}$ = 2 inches ~~say 3 inches~~

This was shown and explained to me on July 8, 1931
C. S. Draper



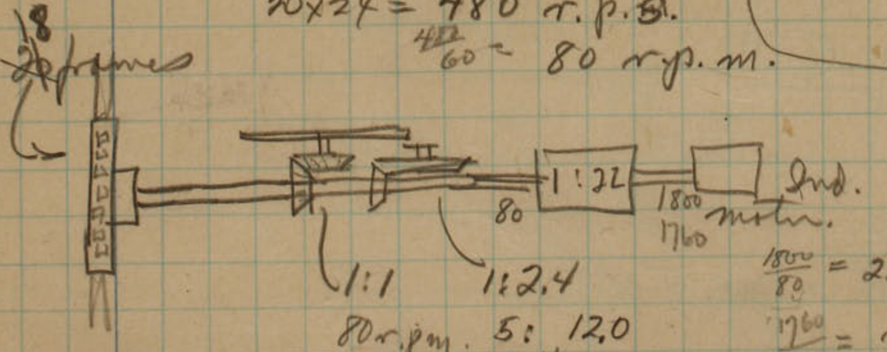
~~Or the sprocket can be run at 33⅓ r.p.m.~~
~~1 rev. in $\frac{1.0}{33\frac{1}{3}}$ = .03 min~~
~~or 1.8 sec~~
~~24×1.8 43.2 frames per rev.~~

18. r.p.m. = 468 r.p.s.

$\frac{468}{24}$ = 19.5 ~~frame~~.

Make sprocket 20 frame
20×24 = 480 r.p.s.
$\frac{480}{60}$ = 80 r.p.m.

18
~~20~~ frames



$\frac{1800}{80}$ = 22.5 ratio.

$\frac{1760}{80}$ = 22.0 ratio.

Cont.

20 frame sprocket.

motor.

contactor to flash the light.

1440.

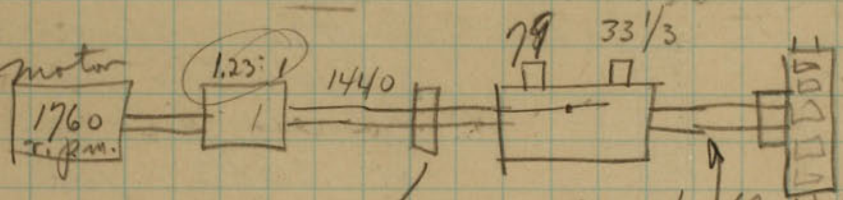
88 r.p.m.

$\frac{88 \times 20}{60} = 29.$

$\frac{1760}{22} = 80$ rpm.

30.

$\frac{80 \times 22}{60} = 29.$



— 10 f.p. rev.

contactor to flash the light.

144. r.p.m. or
2.4 r.p.s.

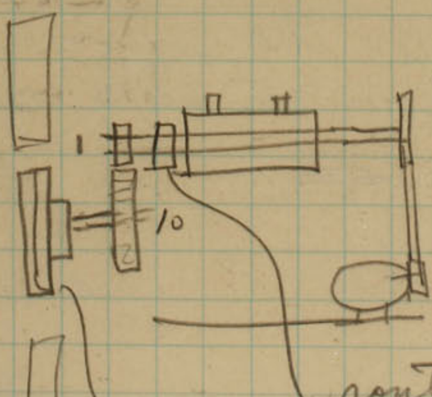
24 f.p.s.

10	2.4	144.
20	1.2	72

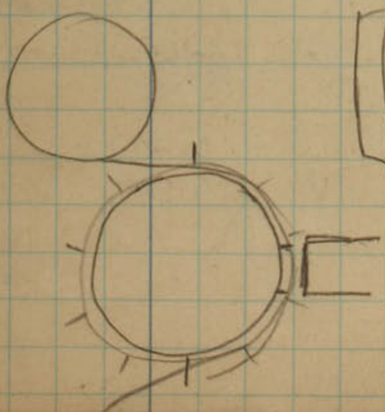
$\frac{1}{960}/1760 = 1.83.$

110 11 9/32

Experimental setup with a
Sprague Visivox projector

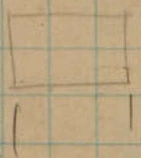


contactor with phase adjustment.



10 f. per rev. sprocket with openings
to let light through.

cont.

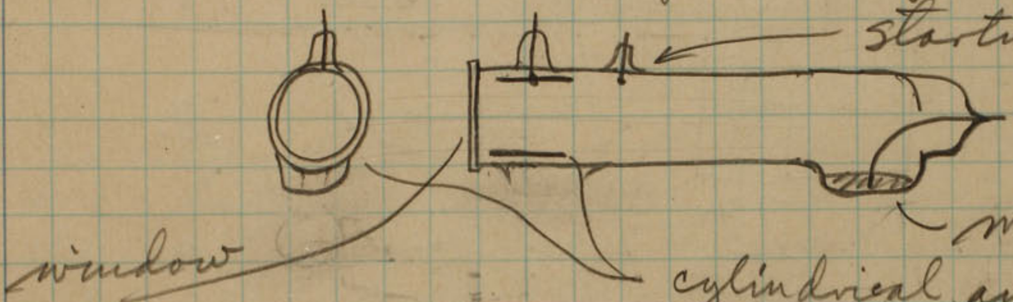


16mm $16/2.54 = .628$ inches.

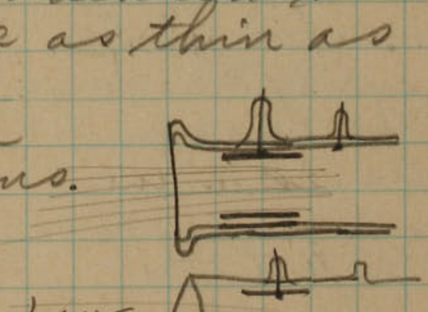
$.628 \times 10 = 6.28$ inch in circumference

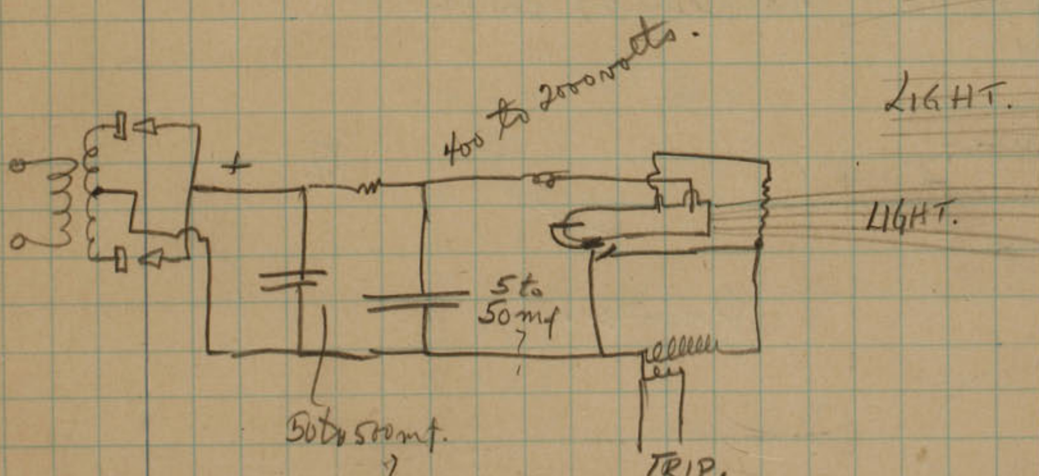
$\frac{6.28}{\pi} = 2$ inches in diameter for the sprocket.

Pulse tube. 30mm Pyrex with plane glass window.



Ventilation will be provided for the back end of the tube. The heat from the anode should be sufficient to keep the window clean of condensed mercury. The window should be as thin as possible. Bell ends may be employed. The window can be a lens.





1– projector.
2 mechanical alterations 1000
3 electrical circuits tubes etc. 1000
4. Search Patents 2000
5. misc 1000

5000.

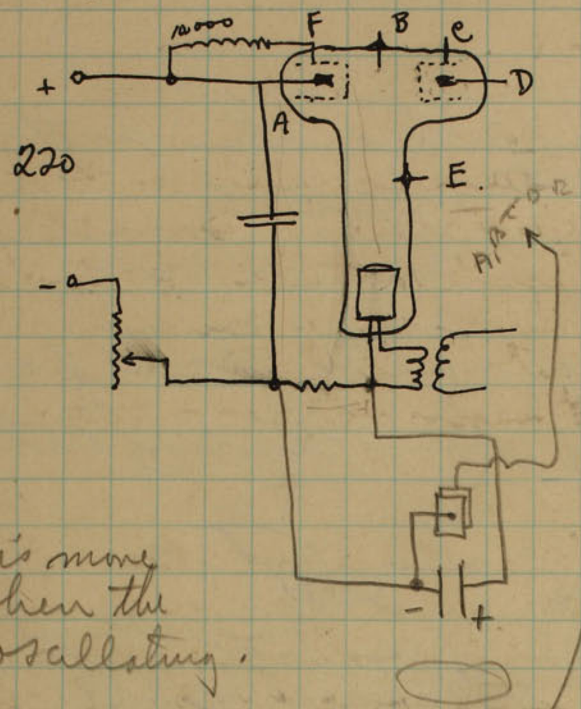
Prelim exp. $500.

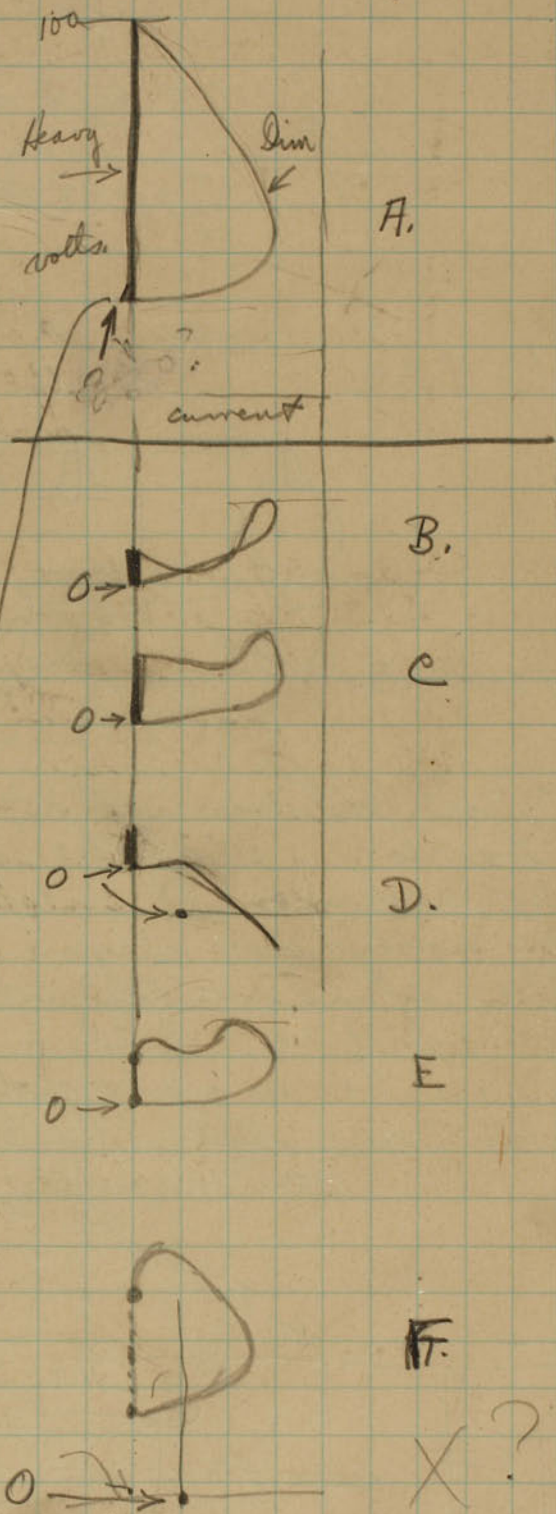
Ordinary projector 100 watts for 1/42 of a sec.
If the light is on 1/1000 of 1/42 of a sec
the light intensity needs to
be that of a 100 x 1000 watt lamp.
"100,000 watt."

$\frac{100000w}{500v} = 200$ amp. (easy!)

July 7, 1931

Dynamic Volt-Amp Characteristics of Special Thyratron described on p. 136. General Radio Cathode Ray Osc.



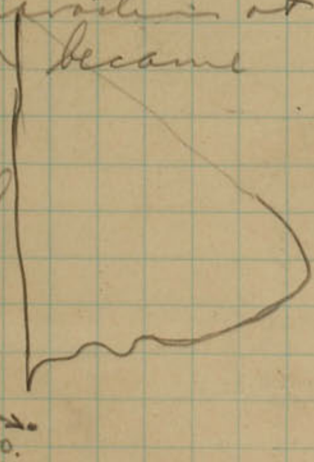


The light is more white when the tube is oscillating.

small kinks showing negative current?

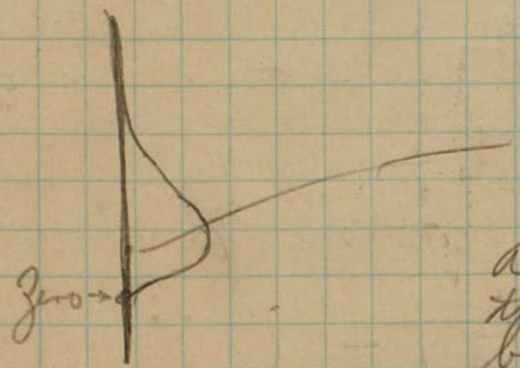
Continued experiment to find zero of these curves. The zero seems to be displaced for the current.

During the tests the characteristic of the phenomena grew slower. Then V-I characteristic at the bottom became like this.



Then the tube stopped oscillating and the arc drop was about 230 volts. Current was flowing in the tube but it was small. I used the sparker on the grid and the conduction with a 42 volt arc drop resulted.

Coil # 6 copper 17 turns 2 1/2" in diam put in series with the discharge.



There is also a bright spot and a small kink at this point. As the voltage builds up the tube starts to conduct but cannot hold the arc.

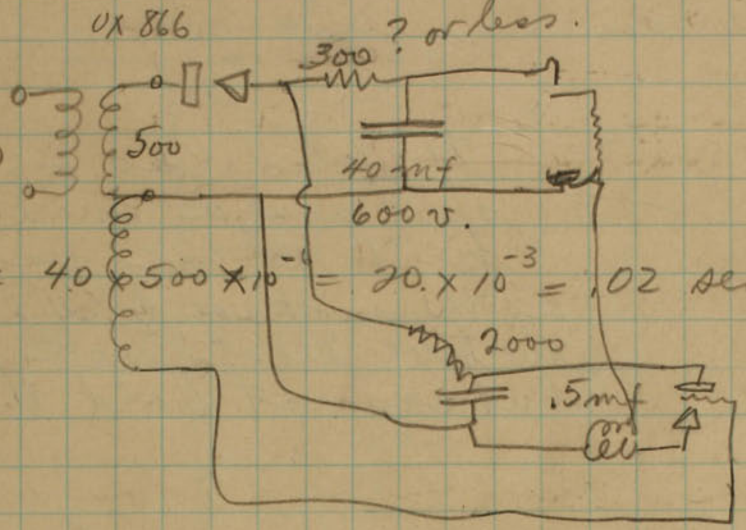
Yesterday G.G. Smith of Raytheon inc brought over his spectroscope and we measured the wave lengths of the radiation of the light from the stroboscope built for the M.I.T. Lab. by McClure and Standard. 12 m.f. were used and the 600 volt tap. The 3 ohm resistor in the discharge was varied from .5 to 3 ohms and the following wave lengths measured when the resistance was .5. These lines do not appear when there is 3 ohms or more in ~~the~~ series with the tube.

The lines that appear for the flash are

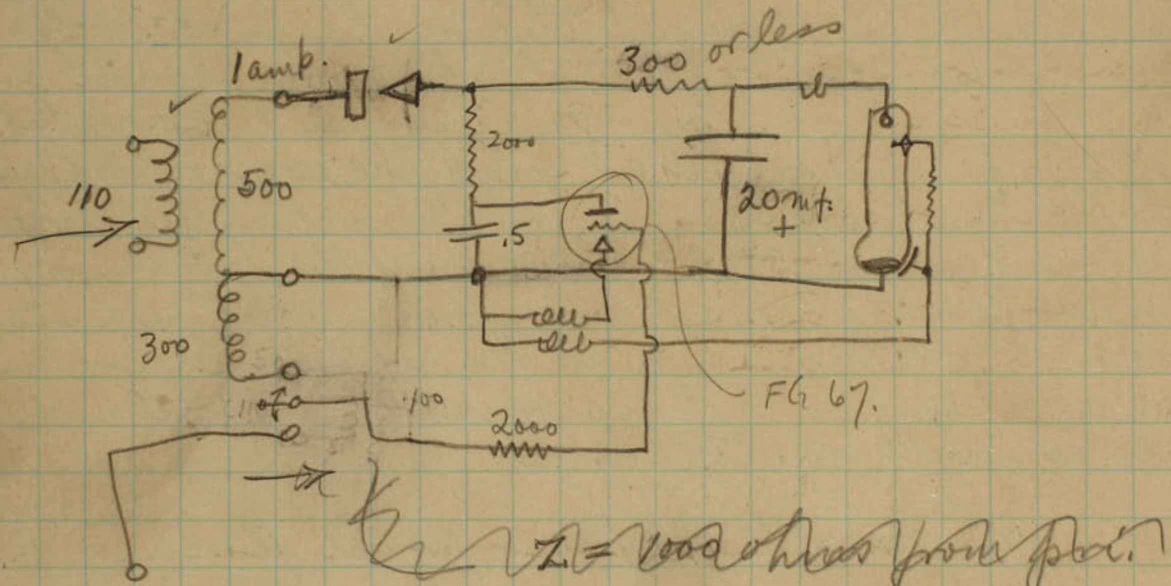
6150 Red
5887
5869
5683
5420
5122
4968
3981. violet.

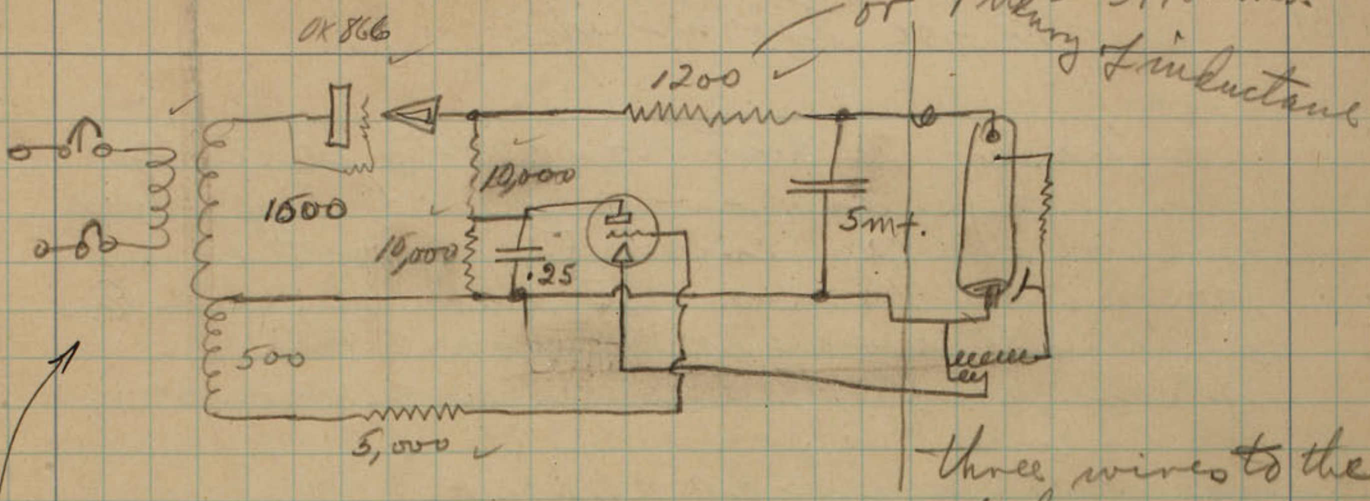
July 7, 1931.
H E Edgerton.

60 cyc ~~Stroboscope~~.



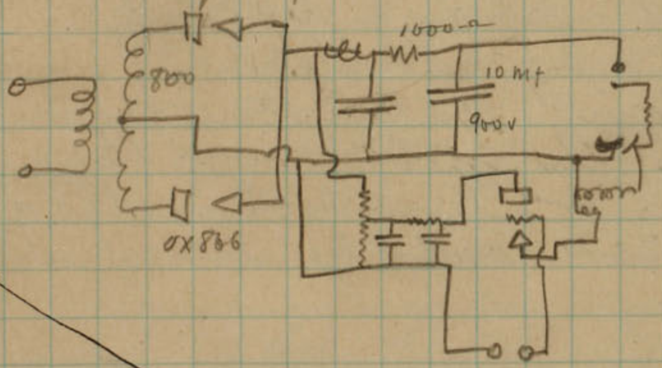
RC = 40 × 500 × 10^-6 = 20. × 10^-3 = .02 sec = .016





I hope to hook this up and try it out tomorrow.

Variable freq. strobo.

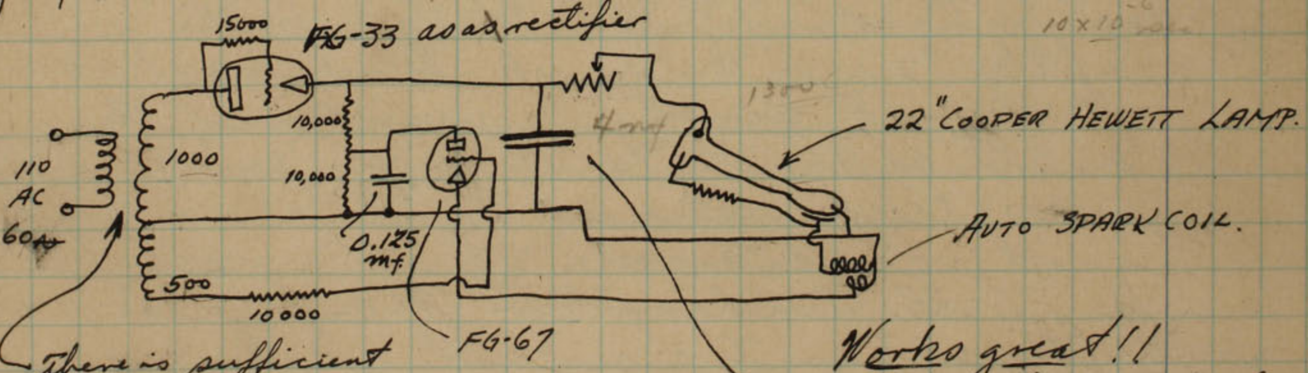


$\frac{E^2C}{2} = \frac{1000^2 \, 10 \times 10^{-6}}{2} = \frac{10^2}{2} = .5 \times 10^2$ joule
$= 50$ joule.

$\frac{\text{Joules}}{\text{time}} =$ watts.

$\frac{50}{10 \times 10^{-6}} = 5 \times 10^6$ watts.
$= 5,000,000$ watts?

July 8 1931. Circuit connected and tried.



There is sufficient reactance in this transformer to cut down the peak current.

Works great!! Capacity varied from 1.35 to 12 mf. the 12 mf overloaded the transformer and caused it to smoke some. With the resistance reduced in the discharge, the color of the arc was very red. The red is apparently a function of the peak current. The higher the peak current the more red.

July 8 1931 Three phase Stroboscope.

Many of the disturbances to electrical power systems are caused by some unbalanced condition on the various phases. It then becomes difficult to say just what the phase angle of a synchronous machine is.

Two methods appear to be feasible. One is to use a positive sequence network to operate the stroboscope so that the phase angle of the rotor to the positive sequence component of the terminal voltage is determined. A second method is to have the stroboscope arranged to flash for each phase voltage. Then three readings will be taken which give the instantaneous angles between the rotor and the different phase or terminal voltages. Three stroboscopes could be used and three cameras.

July 9 1931 Worked on stroboscope arrangement shown on the bottom of p 148. Tried a long Cooper Hewitt lamp in place of the 22 inch lamp. There was some flicker at first. I increased the small capacity to .9 m.f. Some difficulty was experienced by burn out of the grid resistances of the rectifier, a FG-33. Aside from these few minor difficulties the circuit works great.

July 10 1931. Worked on the same stroboscope setup. Pushed the voltage up to 1500 volts on the secondary tap and it seemed to work allright. There was some small sparks or points of light on the anode when the discharge resistance was cut out. The anode also became red hot after several minutes of use. I made a long coil of lamp cord (approximately 30 turns) and put it on the tube lengthways so the magnetic field would be at right angles to the electron stream. The current

from the discharge was put through this coil. It made the light have a mottled affect and caused the tube to heat up. This showed that the arc drop in the tube had been apparently increased.

Koller of the G. E. Research labs. has been here at tech giving a course on thermionic emission. I took him down to see this stroboscope and he was very impressed by the red appearance of the mercury arc when it was flashing with high peak currents.

Biggs of the Hygrade company also saw the arrangement. He invited me out to their factory and I intend to go next week.

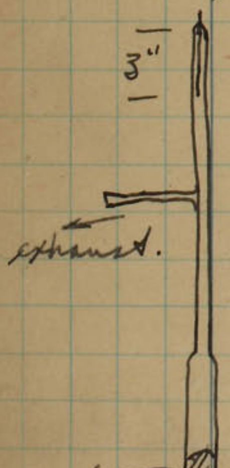
July 11 and 12 Worked on network analyser.

July 13. Worked on vacuum system and cleaned tubes. Blew a special tube for stroboscopic work. It is long and slender.

July 14 Distilled Hg and pumped out tube of form shown on p 143. Cracked seal and bad anode. Hope to have another made tomorrow.

June 15, 1931. Went out to Hygrade lamp Co in Salem and visited the factory. Saw ~~Howard~~ Biggs and Label there. Worked on tubes and set up exhaust system after returning.

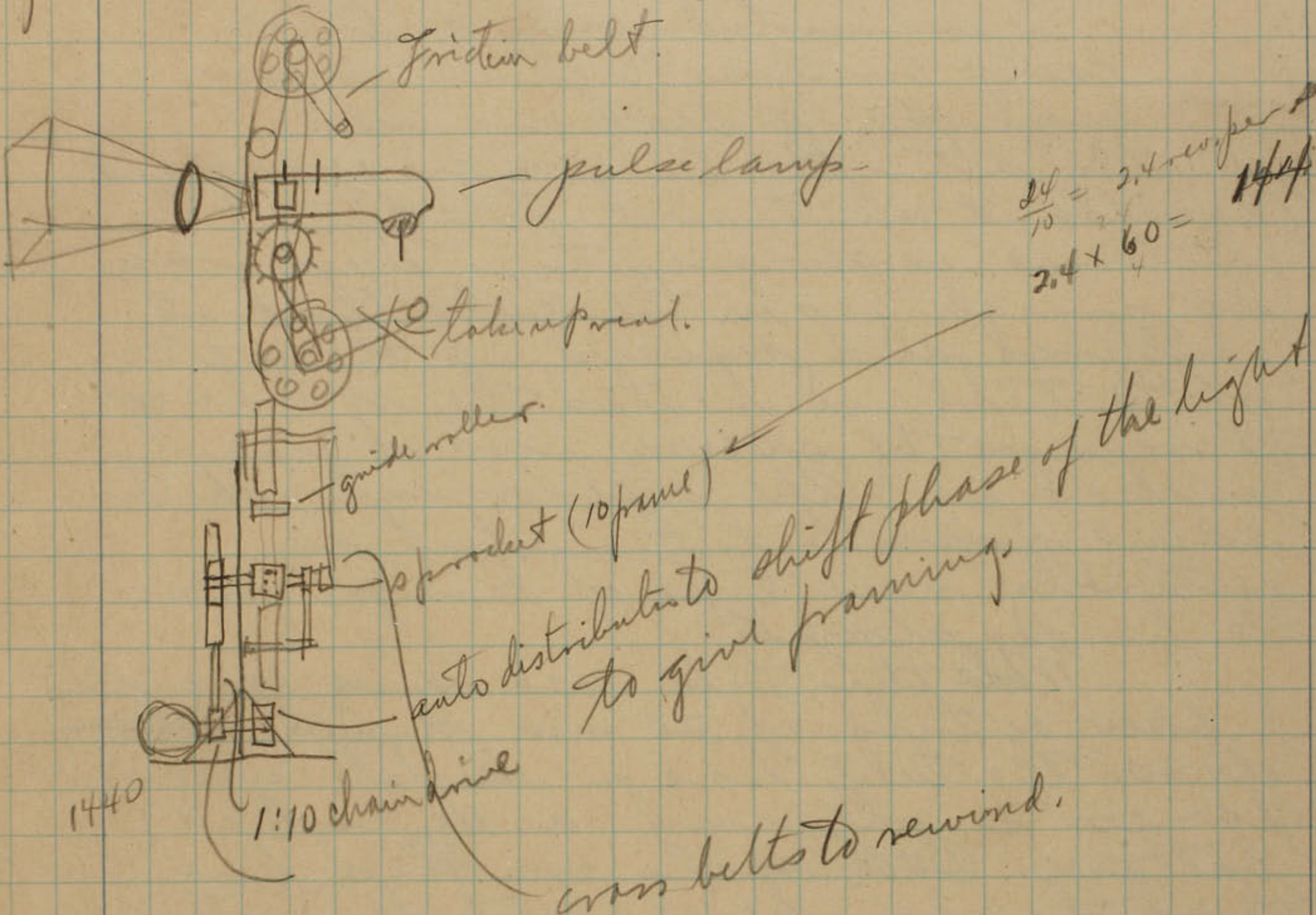
June 16 1931 Exhausted a special tube of 14 mm Pyrex that I ~~built~~ blew. The seals were bad and leaked. This tube was about a foot long and had a Hg pool at the bottom and a graphite anode at the top. I connected my stroboscope circuit, shown on p 147, to the tube while it was still on the pump. As the tube got hot due to the violent discharge the light became a very bright yellow ~~which~~ which was so intense that it was hard to look at. I believe that the tube did not deionize in a half cycle and that the transformer was thus shorted once in a while. The transformer did grunt once in a while probably for this reason. The temperature was up to 140 degrees C (meas. by Hg bulb thermometer). There was considerable gas evolved from the tube during these tests as could be seen from the ionization gage. After some time the leak became so bad that a sufficiently high vaccuum could not be maintained. K Germeshausen helped with these tests.



I built a second Pyrex tube ~~of~~ with a long nickel rod for an anode. This tube is somewhat taller than the other and I hope the seals will not leak tomorrow when I pump it.

The experiments of today show, I believe, that more light is obtained with high pressure. Also impurities apparently help to give better light. I hope I can get all my stroboscopes to give out the intensity that I obtained today.

July 16, 1931. Pulse light Projector.



$\frac{1760}{12} = 14.67$

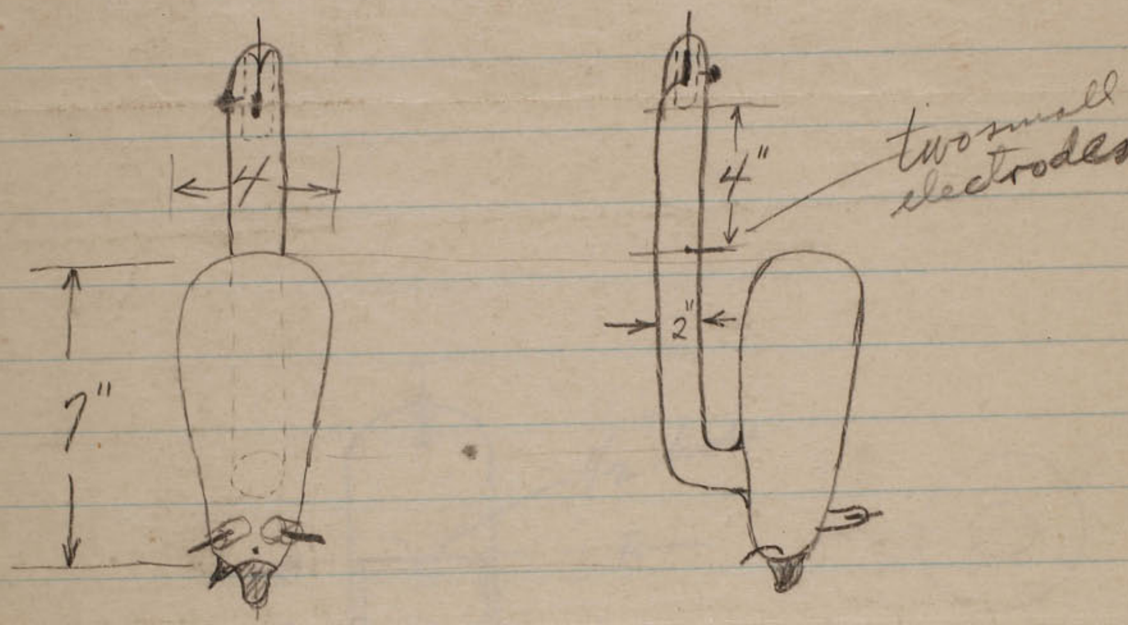
July 17 1931. Exhausted the long 12mm Pyrex tube shown on the bottom of the preceding page. Several leaks were repaired with de Khotinsky cement and a good vacuum was obtained. The circuit of page 147 was used to excite the tube and a very bright sharp light was obtained with a capacity of a little over 4 mf. of capacity. K.S. Germeshausen rewired the electrical circuits and put the apparatus ~~them~~ in a box so that the portability was increased.

July 18 1931 Experimented more with this long slifon tube. Prof. Stockbarger, Johnson, and Burns of the radiation lab. saw the arrangement in operation and we plan to take some spectrograms next monday a.m.

July 19, 1931
A. E. Edgerton.
K. S. Germeshausen
G. F. Brown.

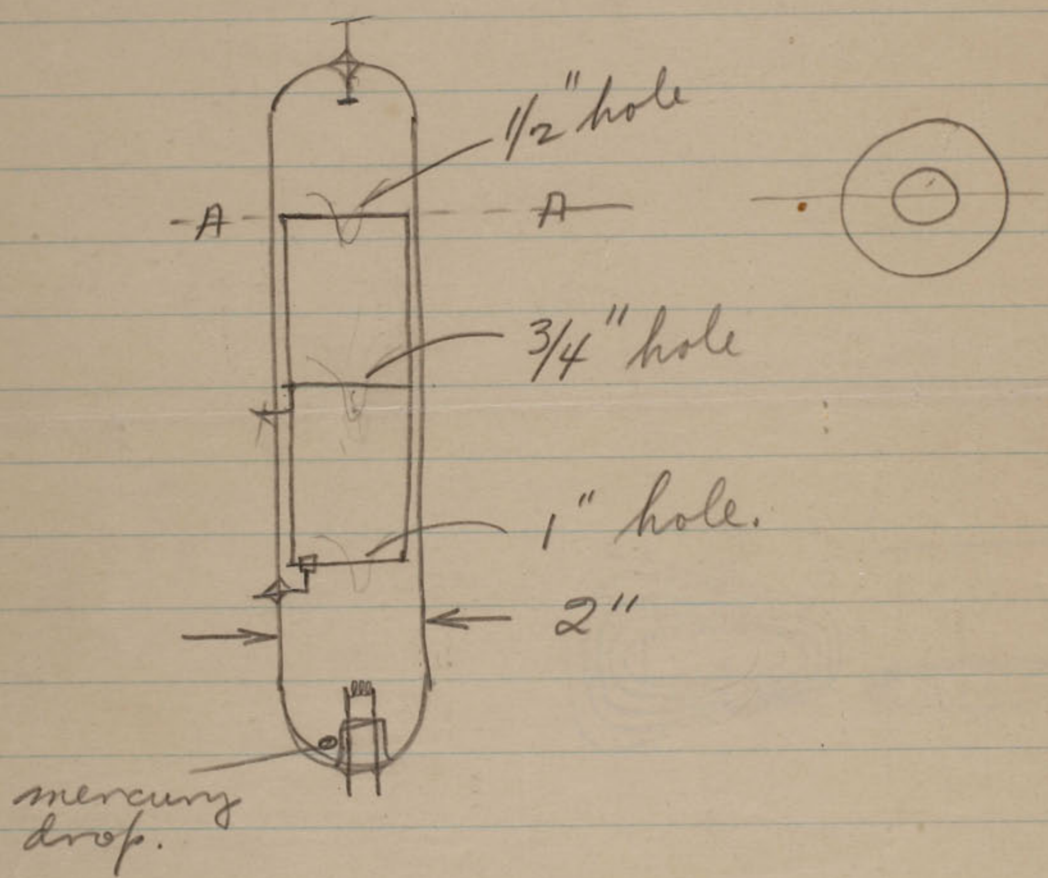
Experimented with a pulse lamp similiar to those shown on page 143. A seal cracked shortly after the tube was energized. Cemented it shut and tried to continue experiments. There was so much gas in the tube that it sputtered and messed up the walls of the tube. I heated the window to remove the scum and it nearly sucked in. The experiments show some possibilities but an entirely new type of design needs to be employed.

~~While~~ this tube was being exhausted I blew a tube of 20 mm Nonex ~~tubing~~ glass. The tube has a nickel cylinder ~~for~~ an anode and a Hg pool at the ~~bottom~~. Both seals cracked but I think they can be cemented together for the preliminary experiments.



Mar, 1, 1931.
H. E. Edgerton.

Stroboscope ~~tube~~.



Special hot-cathode mercury-arc tube.

H. E. Edgerton
M.I.T. Feb. 13, 1931.