HAROLD E. EDGERTON

PAPERS

MC 25

Series III

Laboratory Notebooks

Number 7

Dated April 28, 1936 to May 27, 1937

MASS. INST. OF. TECH.

~~HARVARD~~ UNIVERSITY

COMPUTATION BOOK

NAME	Number
HAROLD E. EDGERTON	7

Course

Used from APRIL 28, 1936, to MAY 27, 1937.

Harold E. Edgerton
Mass. Inst. of Tech.
Room 4-111.
April 28, 1936.

p 30 July 1936 H. Birds. Hellenes Webster

HARVARD UNIVERSITY

COMPUTATION BOOK

GENERAL INSTRUCTIONS

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

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

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

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

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

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

* * * * * * * *"

Jan. 1. 1937. 15 384,71 1936 income
5662.26 exp
3195.84 Edg.
3586.13 GERM
2940.48 NERB

HARVARD CO-OPERATIVE SOCIETY

Cambridge, Mass.

April 30 1936
H. E. Edgerton.

Continuation of Experiment with argon lamps (stroboscopic) etc.

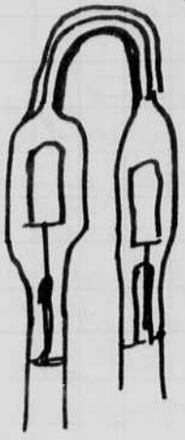
Yesterday Germeshausen and I tried a helium filled lamp. 1400 volts was used across it. The tube consisted of a 6" tube of 8 mm O.D. glass with 20 mm glass as ends. The cathode was a Ba Cl + Mg or al type. The light was not comparable with the light from the argon lamp. Helium pressure for this tube and voltage about 1/2 cm or less. Color bright red? hard to discribe. It may be that the helium is not pure enough. The tube was not sealed off since with helium gas since it was not bright enough. I filled it with argon at 6 cm? ± for use as a stroboscopic lamp.

Richard Evans in the spec. lab. reports that the lamp I made for him is working fine. He now gets well exposed pictures with 2 mf (400 v ?±) where he before got poorly exposed pictures with 16 mf using a Hg lamp. His argon lamps have a pressure of 4 cm and they occasionally fire by themselves. The tubes may have been hot when sealed off so that the pressure is now less than 4 cm.

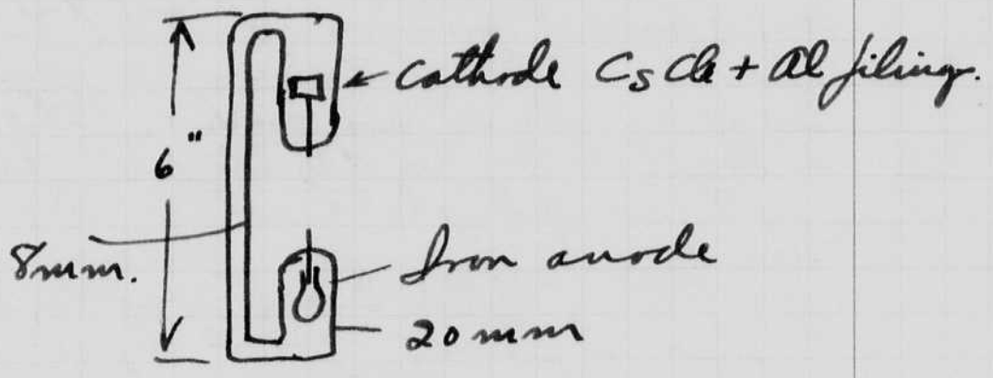
The Chem dept glass blower made a tube of the variety that have been recently made by Macalaster Scientific Co and I pumped it while eating at Walters tonight. It was sealed off at 6 cm when cold after being run and flushed several times on the pump. The pressure is too high as it starts with difficulty on the circuit operated by the stroboscope.

Photographic tests.

Quartz High Pressure lamp.



argon lamp. 6 cm pressure

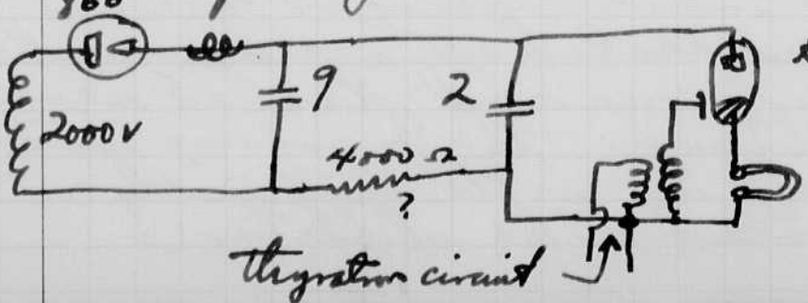


Leica Camera f 12.5. Lamp and surrounding

1	Hg lamp.	1 flash	?
2		14	
3		20	
4	argon	1 "	?
5		14	
6		20	
7		40 or 50	?
8		60	

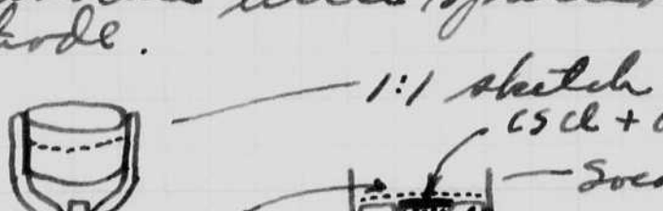
The voltage was about $\frac{80}{110} \times 2800$
capacity about 2 microfarads.
freq about 2 per second ±

These pictures will give an indication of the amount of light from these two sources.



May 1 1936
H. E. Edgerton.

The tube shown on the opposite page does not run consistently with the spark from the stroboscope oscillator (¼" spark). The tube was opened and put on the pump again, sealed off this time at 4 cm of argon. The pressure is still slightly high although operation is satisfactory most of the time. This tube was run all day today (6 hours) and there is very little sputtering of the cathode.



Another tube identical was made this afternoon by May Bich and I pumped it during supper. I sealed it off with 2 cm of argon when cold. Works ok in circuit. Started running at 6:45 pm 2 mf 1200 ± 20 cycles.

May 4 '36 — The tube with 2 cm was put into operation for "open house" on May 2 ~~about noon~~ in the morning and it ran until about 6:30 pm at 20 cycles per second. It was used to observe water drops coming from a nozzle, the flow of water set up by a small pump. 2 micro farads at about 1200 volts were used across the tube. Some sputtering this time but it was on the anode due to arc backs, cathode spots were in evidence on the anode.

The tube broke when some water was thrown on it by one of the spectators. Then a neon tube was put in its place until 10 pm the end of the show.

May 4 '36 cont
H. E. Edgerton.

Mr. Wagringer repaired the broken tube making the length of 8 mm tubing equal to 12 inches instead of 6.

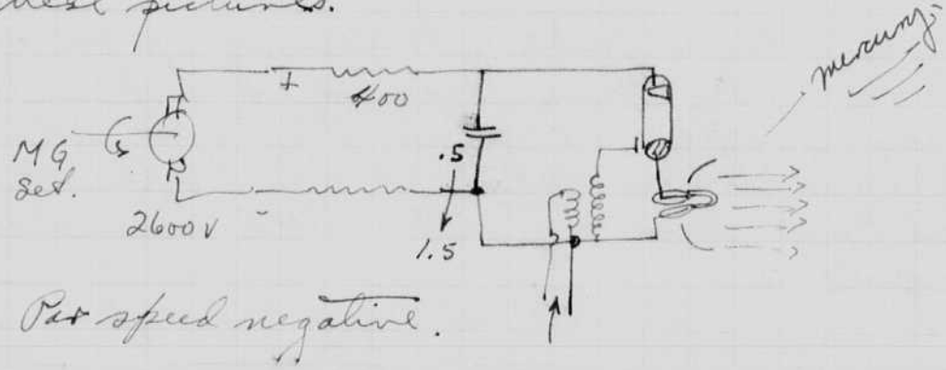
Pumped a 6" tube and filled with neon at 20 cm. 1200 volts and the strobotac oscillator were not powerful enough to kick it off.

Retubulated, baked, pumped and filled to 14 cm. This time it held over at first but ran off after warmed up.

I put 2.2 cm of argon in the 12" 8 mm diam tube.

Mr. Jones of the Saco-Lowell Shops brought in a roving machine that was cut away to show the action of a folder type of wheel. Movies were taken.

A quartz high pressure lamp was used for these pictures.



f-8 Par speed negative.

Notebook # 7

Filming and Separation Record

___ unmounted photograph(s)

4? negative strip(s) 1 neg. strip between pg 4-5
3? neg. strips inside mounted envelope pg 4

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

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

Item(s) now housed in accompanying folder.

May 4 '36 cont
H. E. Edgerton.

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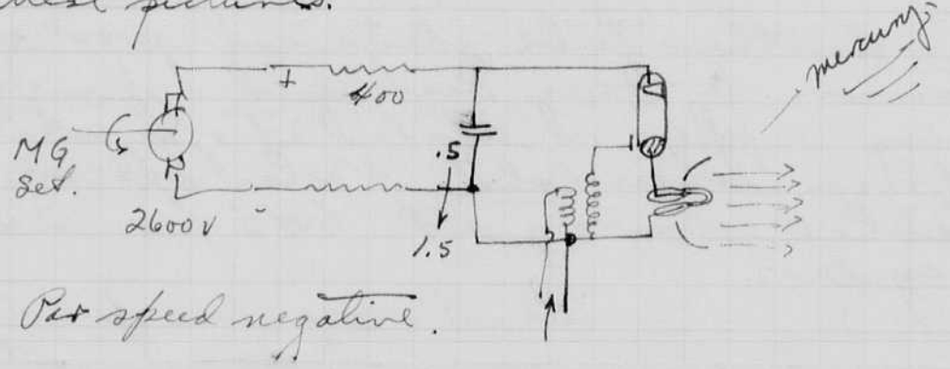

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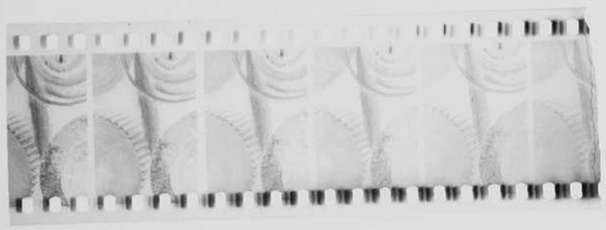
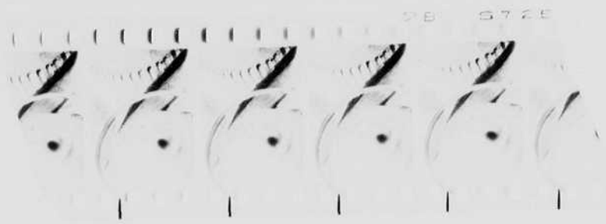
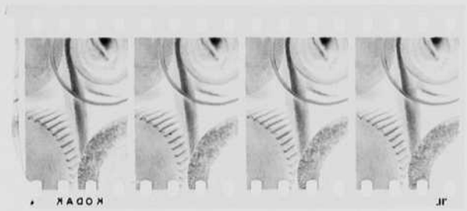
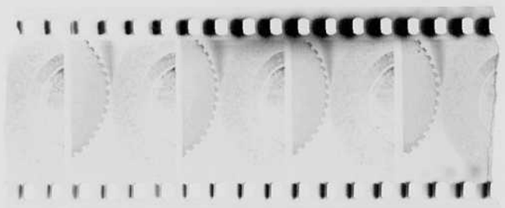
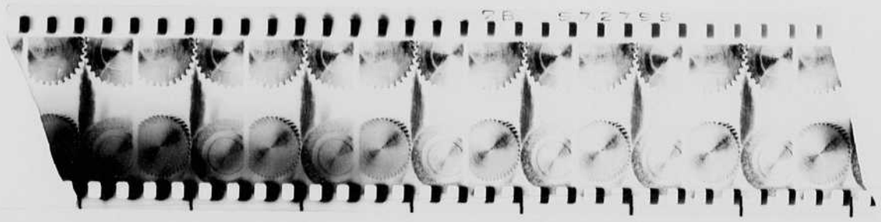
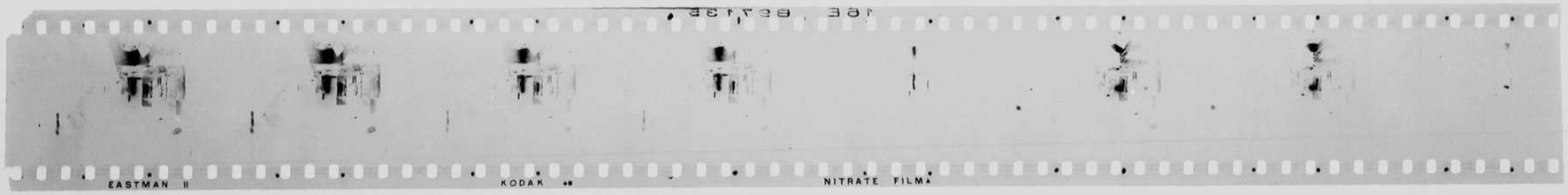








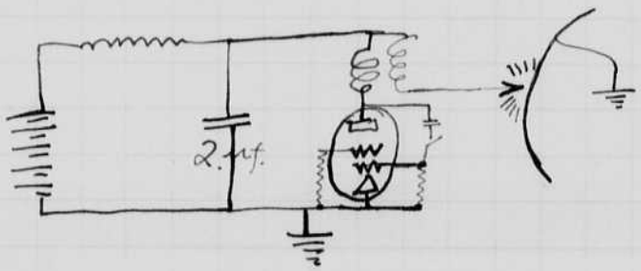



EASTMAN
KODAK
NITRATE FILM

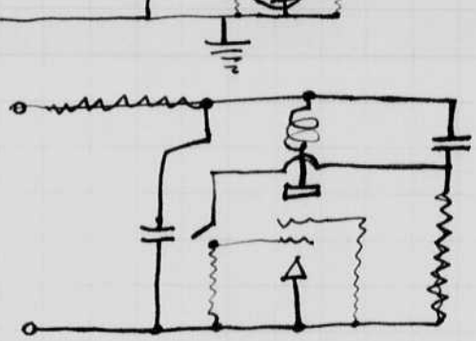
May 8, 1936.
H. E. Edgerton.

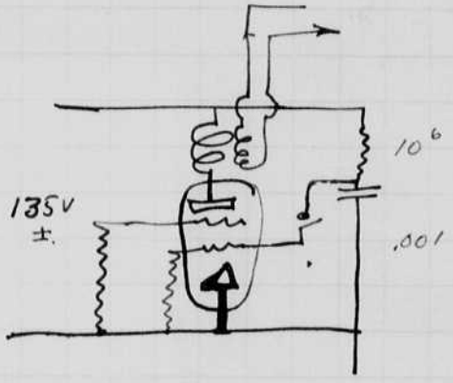
Yesterday I drove to New Haven at 2 pm and showed movies to the A.I.E.E. convention. Met Mr. Teare, Mr. Conrad, Mr. Rudge (I.E.) and others. This morning I spent about an hour at the Winchester plant with Mr. Pugsley, Mr. Robinson, and others discussing barrell vibration problems. Arrived home at 2 pm.

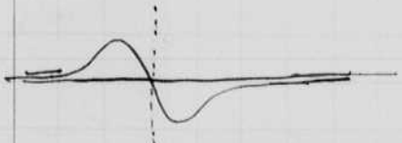
Aberdeen type chronograph operated by strobotron tubes.

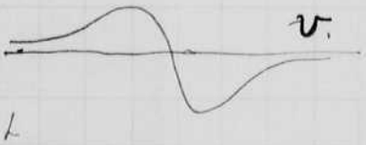


1/16th 80 mph/sec
1/8 inch
800 x 12 x 8 = 80,000
1/4 mike.









0.1

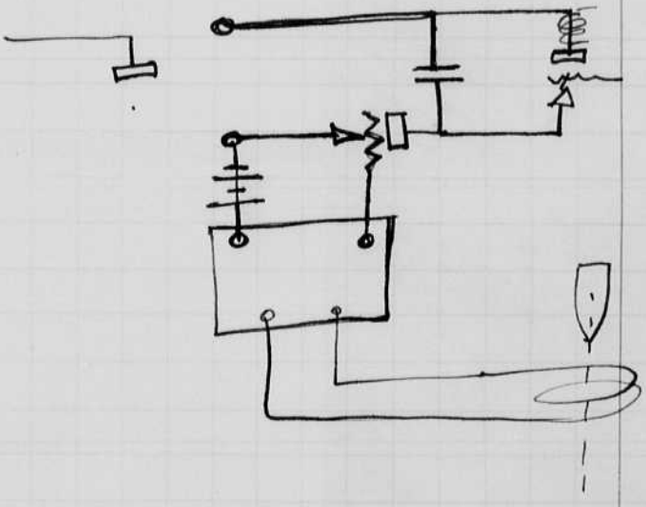
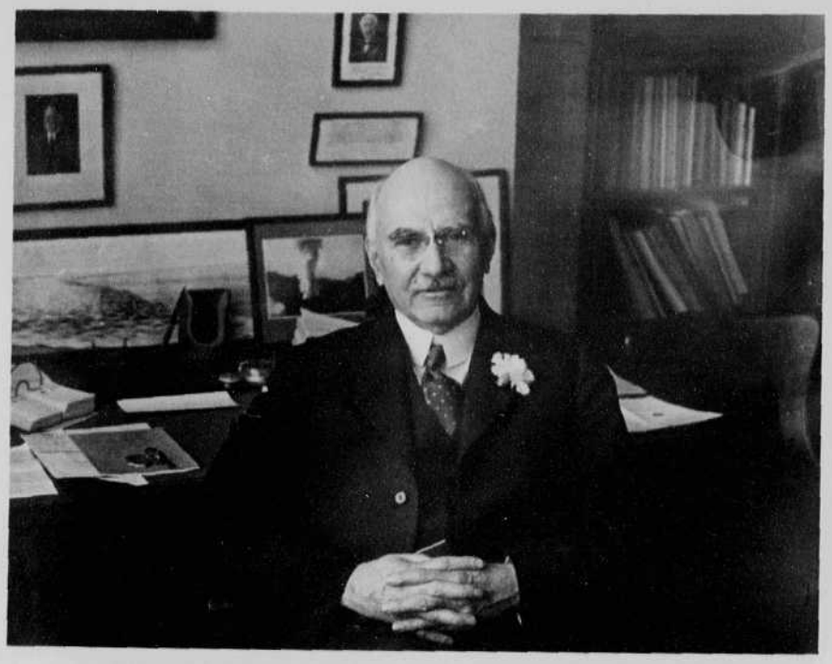
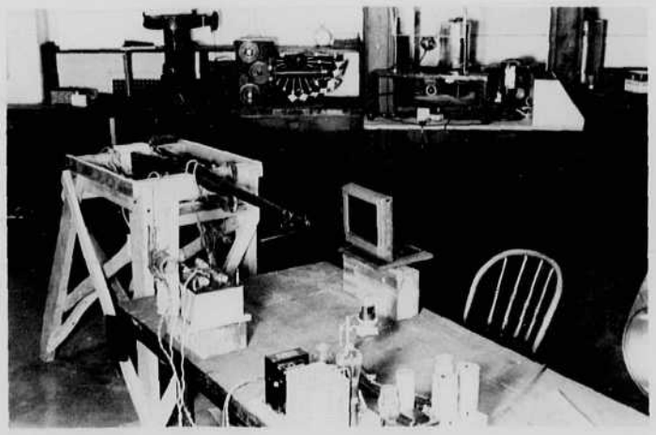


PHOTO OF
D. J. JACKSON
AT HIS DESK.

TAKEN MAY. 1935.

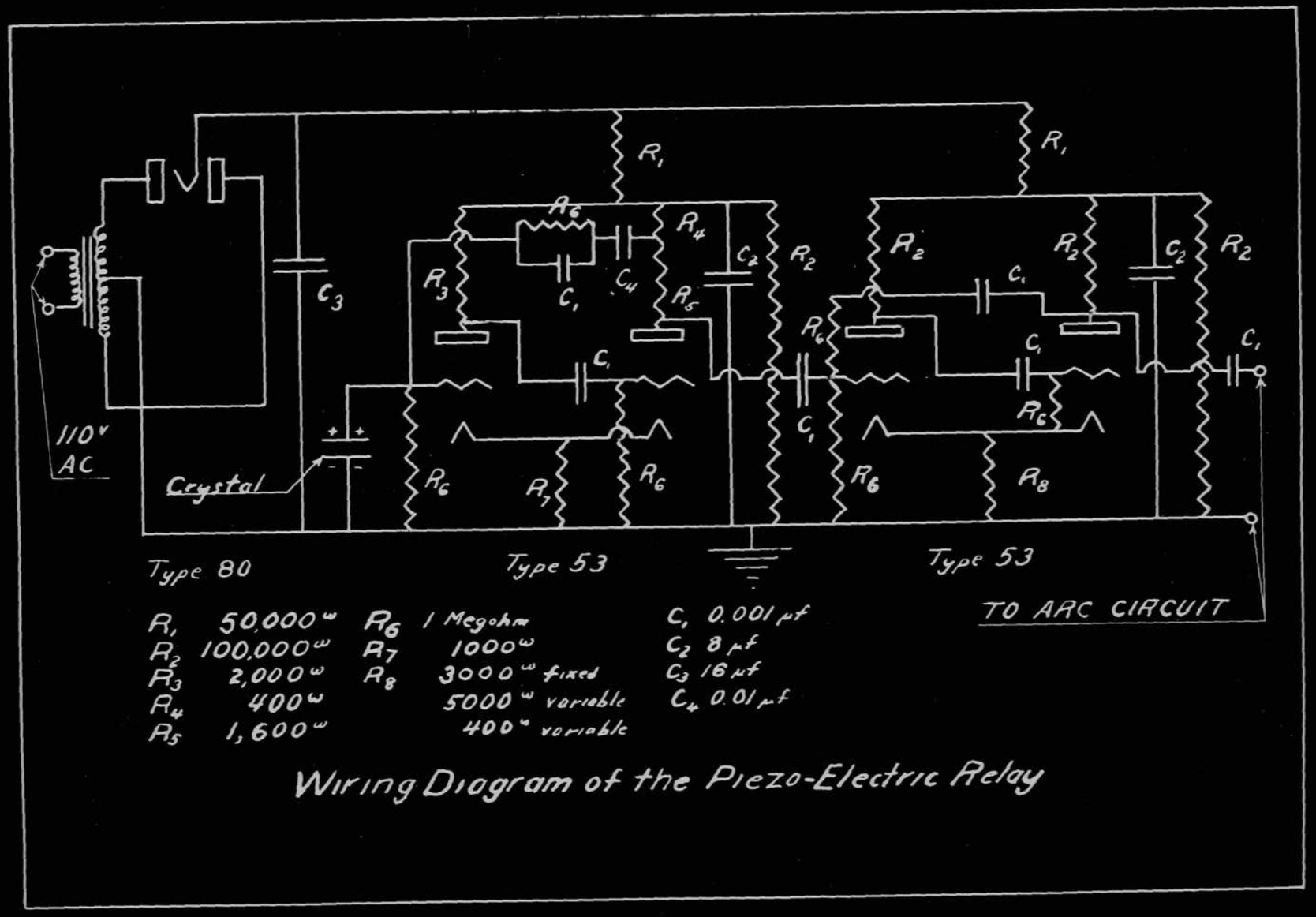


30-40
RIFLE



↑ CRYSTAL & AMP.

Crystal pickup amplifier



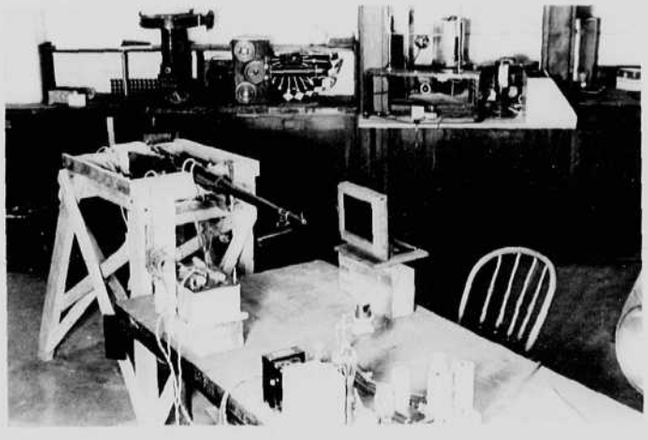
R_1	50,000 ω	R_6	1 Megohm	C_1	0.001 μf
R_2	100,000 ω	R_7	1000 ω	C_2	8 μf
R_3	2,000 ω	R_8	3000 ω fixed	C_3	16 μf
R_4	400 ω		5000 ω variable	C_4	0.01 μf
R_5	1,600 ω		400 ω variable		

Wiring Diagram of the Piezo-Electric Relay

PHOTO OF
D. J. JACKSON
AT HIS DESK.

TAKEN MAY. 1935.

30-40
RIFLE



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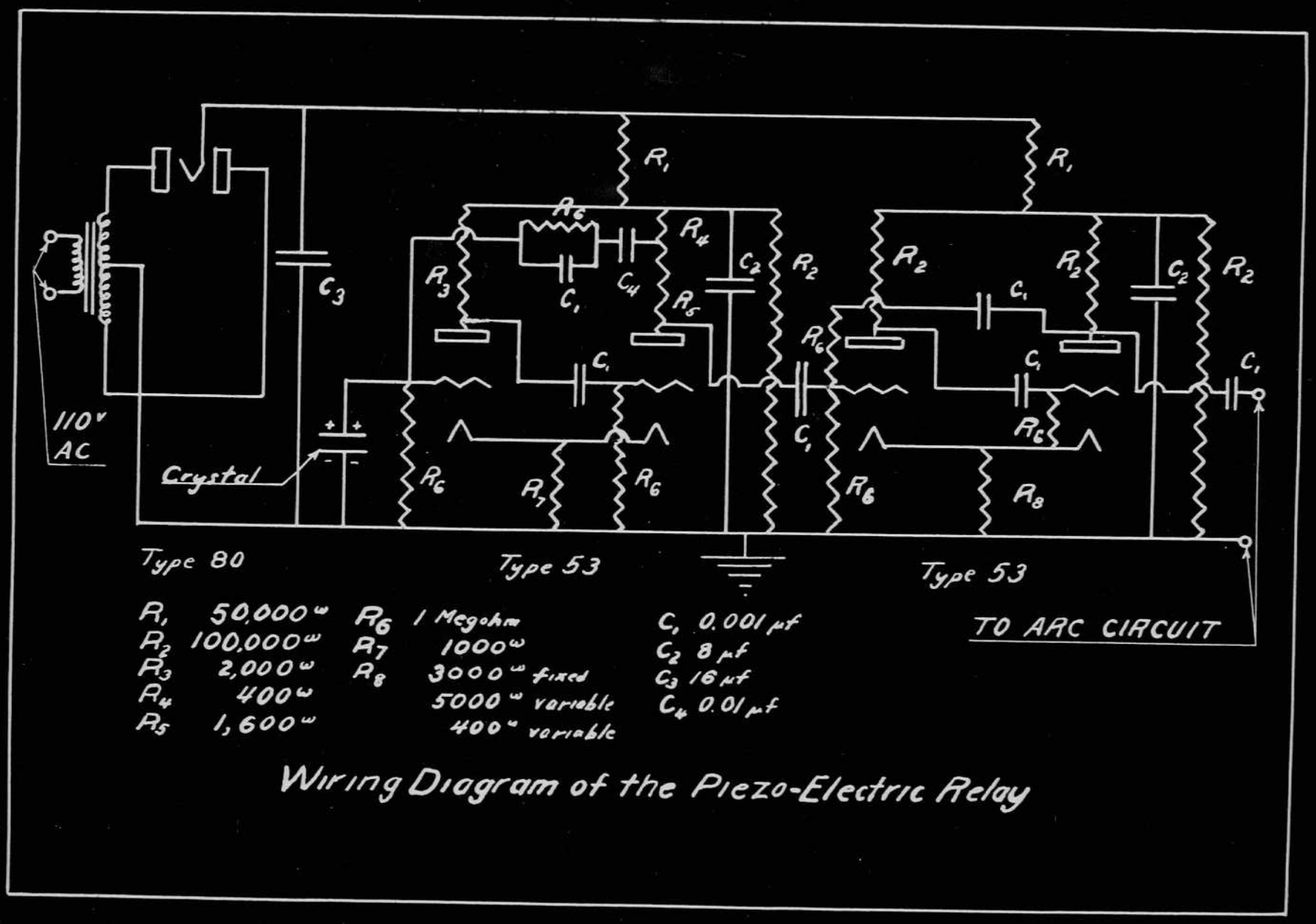
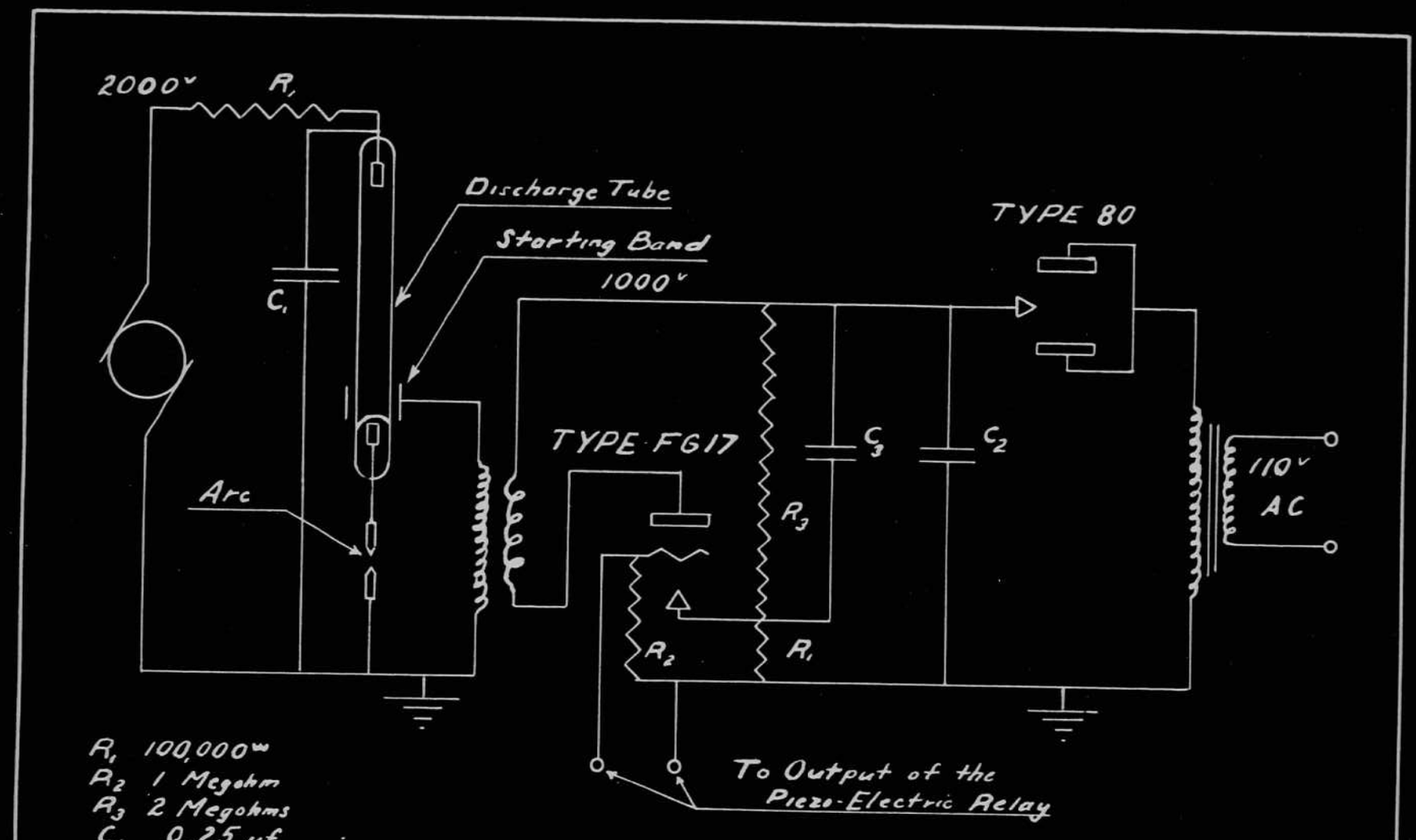
crystal pickup amplifier



R_1	50,000 ω	R_6	1 Megohm	C_1	0.001 μf
R_2	100,000 ω	R_7	1000 ω	C_2	8 μf
R_3	2,000 ω	R_8	3000 ω fixed	C_3	16 μf
R_4	400 ω		5000 ω variable	C_4	0.01 μf
R_5	1,600 ω		400 ω variable		

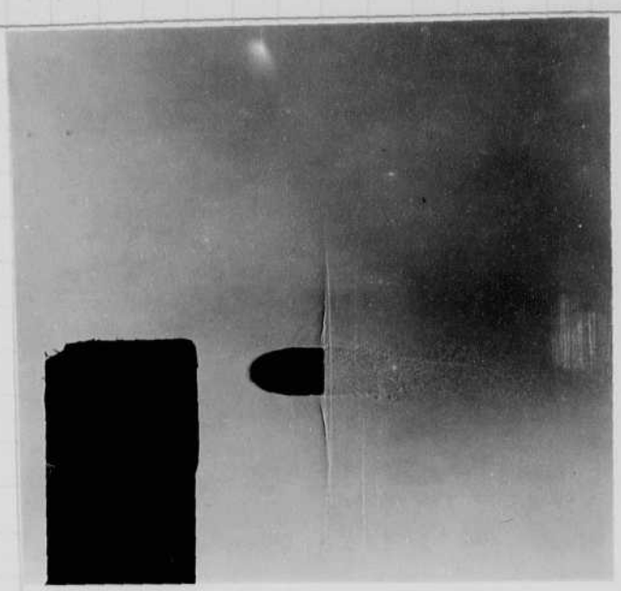
Wiring Diagram of the Piezo-Electric Relay

Thyratron and light circuit.



R_1 100,000 ohms
R_2 1 Megohm
R_3 2 Megohms
C_1 0.25 μf
C_2 14 μf
C_3 0.125 μf

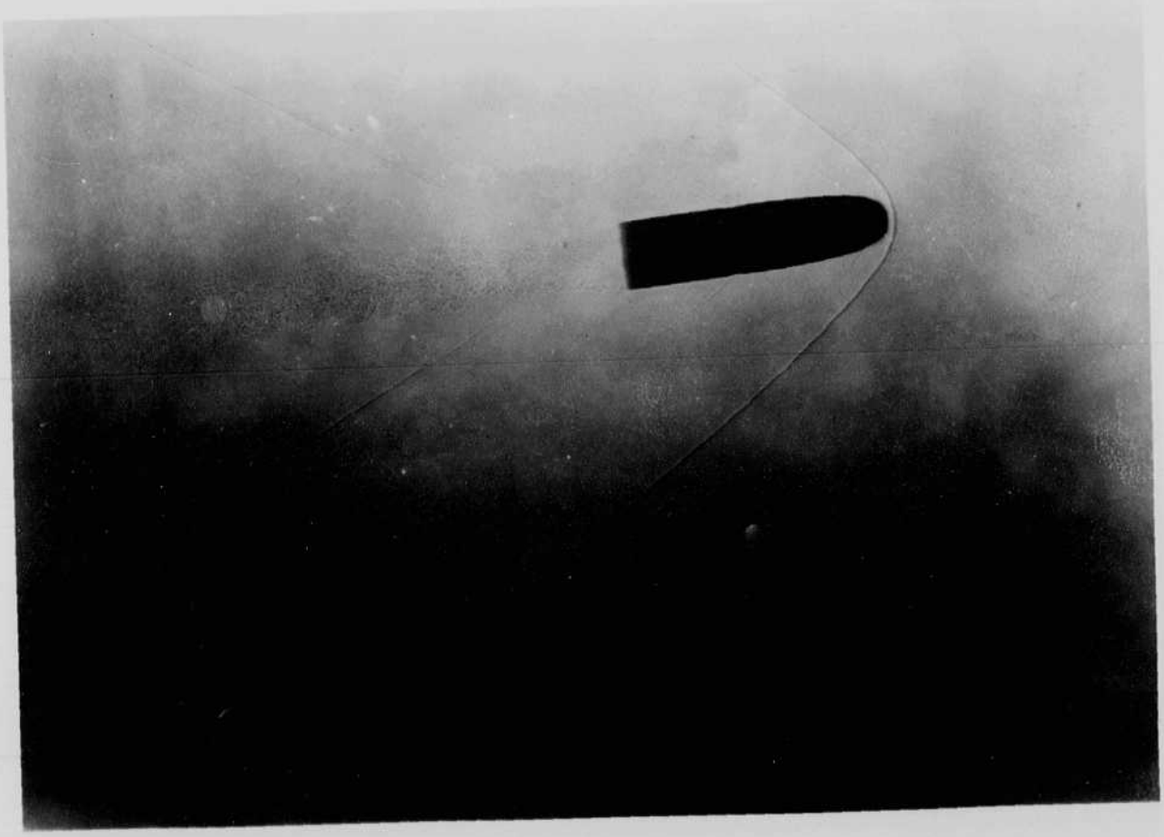
Arc and Thyratron Control Circuit

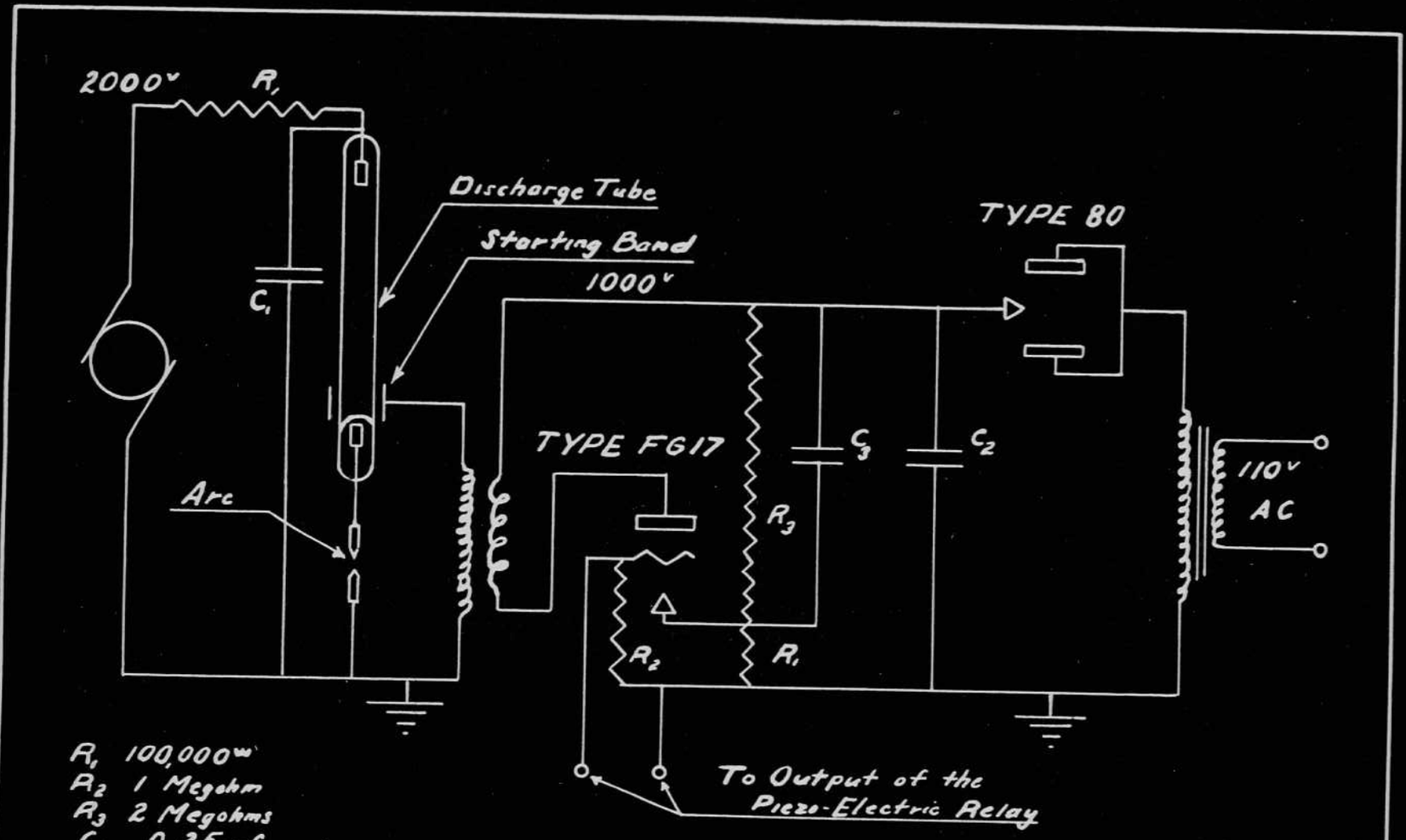


← 22 LONG going less than the velocity of sound

These pictures were taken Sat evening May 9 working with abbott.

Krag. 30-40

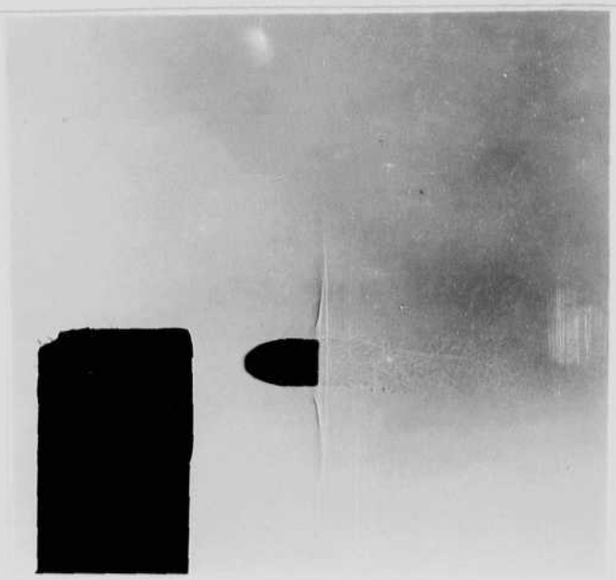




R_1 100,000ω
R_2 1 Megohm
R_3 2 Megohms
C_1 0.25 μf
C_2 14 μf
C_3 0.125 μf

Arc and Thyratron Control Circuit

Thyratron and light circuit



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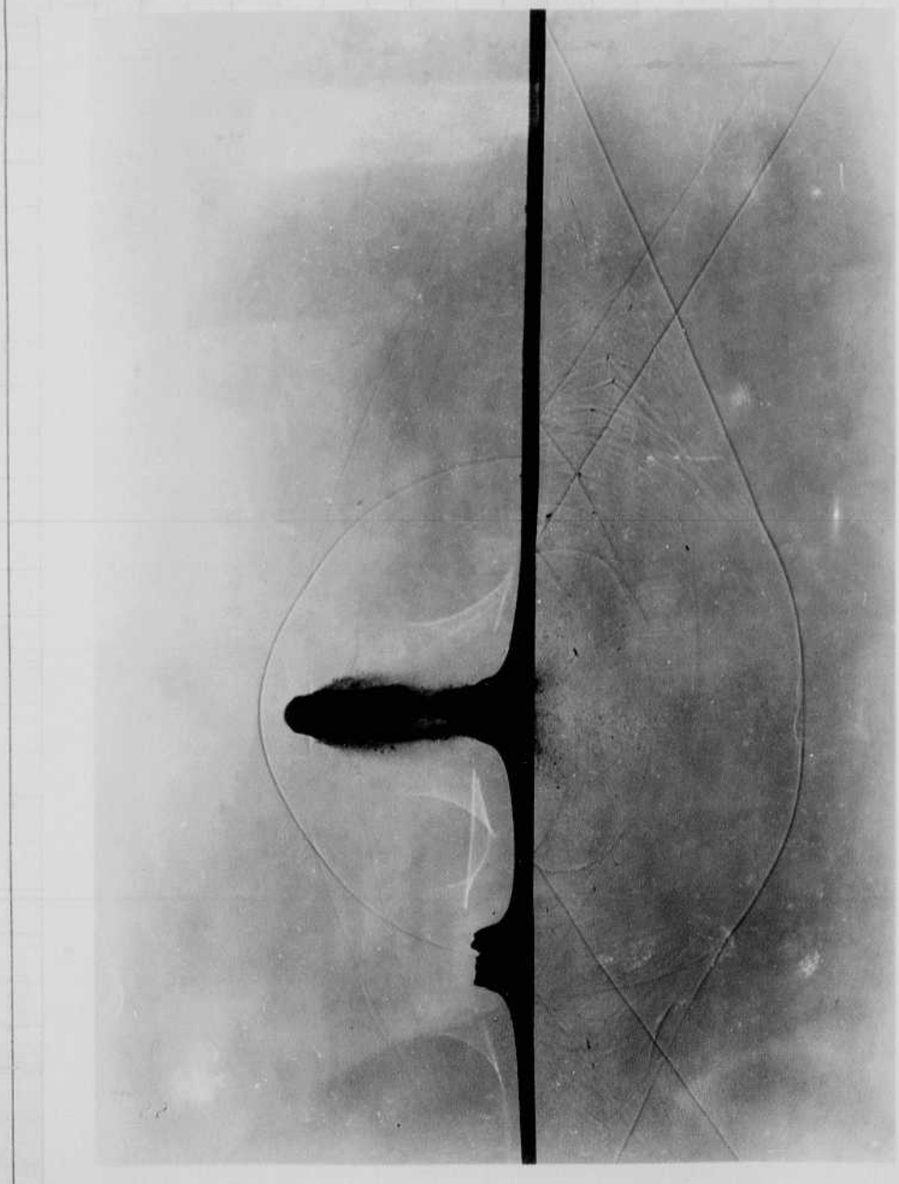
↑ 22 long rifle

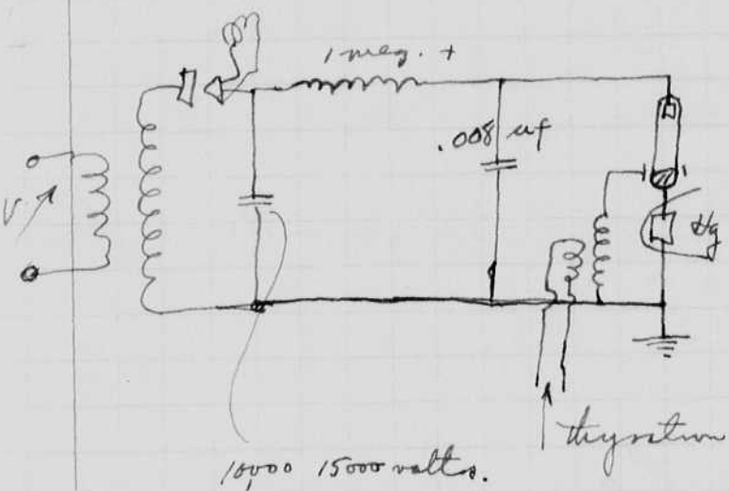


Same going through a thin Aluminum plate.

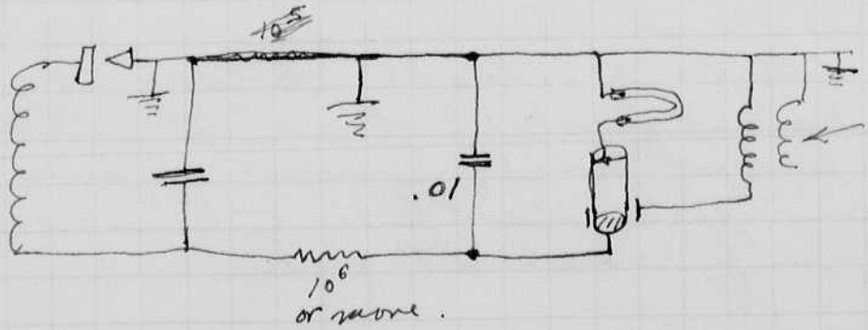
May 10 1936.

Three pyrex tubes of the type designed by Germeshausen have been made by Macalaster & Bicknell Co for use in taking pictures of bullets by reflected light. They will be filled with mercury to 1/2 atmosphere (about 350°C) and with hydrogen gas to deionize the Hg vapor. 3 cm of Hydrogen will be about the amt to try. 2 mm are now used in the 2000 volt tubes.

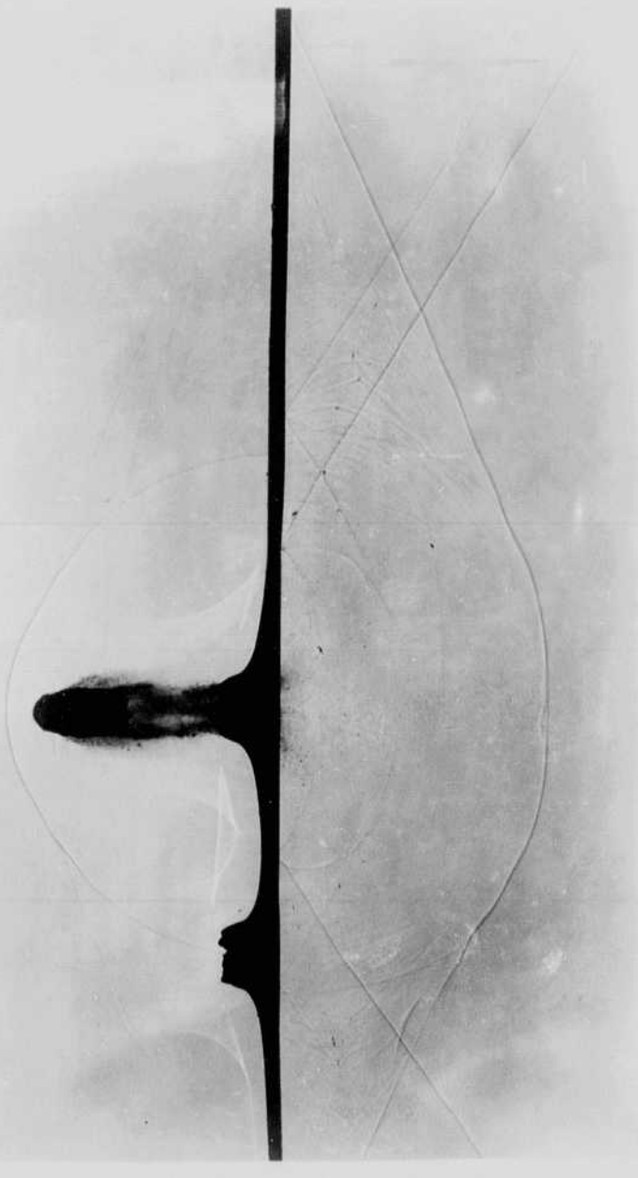
The circuit constants for the first tests will be the following.



The high voltage filament on the kenotron must be grounded. This was tried but sparks over heater or lamps resulted. Circuit must be changed to the following.



22 long rifle



Same going through a thin Aluminum plate.

May 15 1936.

Three pyrex tubes of the type designed by Dr Mesthaus en have been made ~~and~~ by Max Ahrsten & Bidemek Co for use in taking pictures of bullets by reflected light. They will be filled with mercury to 1/2 atmosphere (about 350°C) and with hydrogen gas to deionize the Hg vapor. 3 cm of Hydrogen will be about the amt to try. 2 mm are now used in the 2000 volt tubes.

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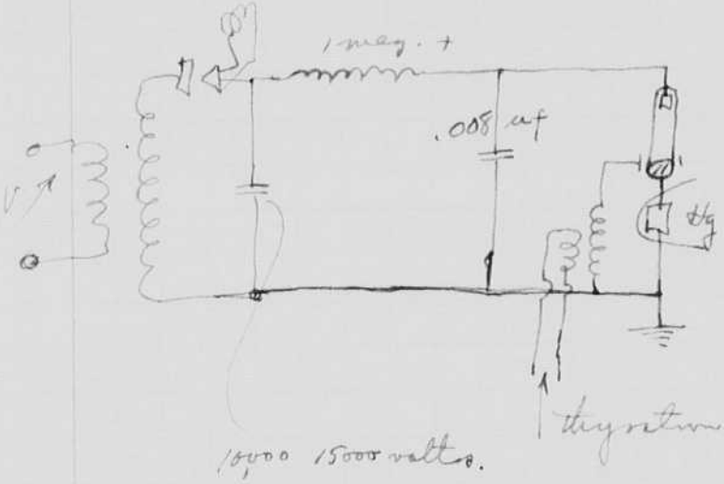

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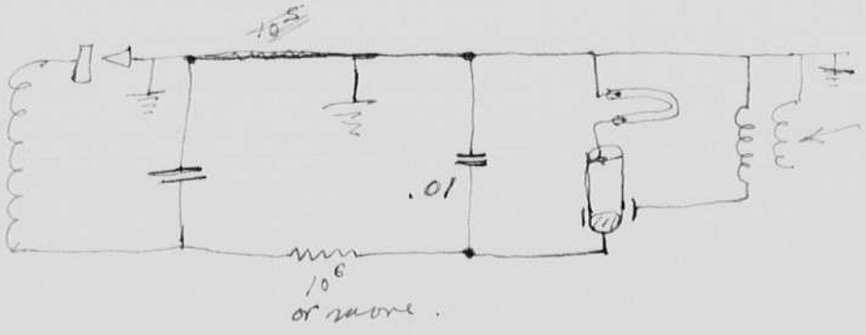
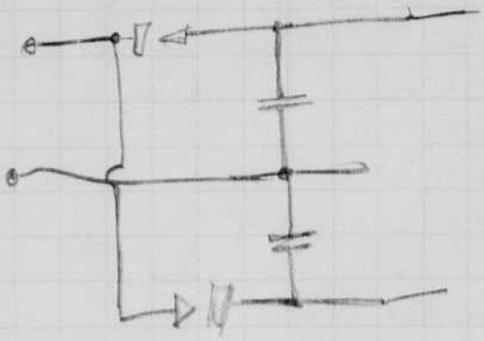




2-2525 { .3 - 115 cath. 34 watts cath heat.

25 x .3 = 7.5
6.3 x .8 = 5.4
13. watts.

Assumed design of Stabotac with transformer for filaments only.

25V .3a (2526.)
6.3 .8a ? twin triode like 53 except with 6.3V filament.

May 22 1936.

On the 20th I spent all afternoon experimenting with a U shaped tube designed to fit the General Radio 548 stroboscope. The tube was leaky however and therefore the experiments useless.

Yesterday I made two tubes. The first was filled with 1½ cm of argon. 12 mm U tube CsCl+Al cathode. I took it over to S.R. and it worked ok in the stroboscope except for the lower capacity. Voltdrop then resulted. The second was filled with neon at 6 cm.

An interesting experiment resulted with the neon tube. If the sparker is connected to the bend of the U and there is no voltage between the electrodes, a red

glow appears in the tube which is the characteristic red glow of neon. Now if the ~~plate~~ supply voltage is connected across the ends of the tube with a 2 mf condenser (3500 ohms to about 600-900 volts) the glow in the tube is blue when the sparker is several inches from the bend of the U. If the sparker is brought closer then the condenser discharges suddenly into the tube resulting in a red flash of light which is very bright.

Germeshausens suggestion of writing Bell & Howell co. seems to be a good one. They are sending a film editor and we are going to try to adapt a stroboscope to it.

May 26 Made two argon lamps to fit portable Strobo. yesterday 2cm argon 19 cm tubing. Also made a capillary tube with 72 cm of the type that Germeshausen has been using.

12mf 1400 v f8. plates.

20 mf. 900 v.

f 3.5 three or 4 p. Super Pan. Sept. 20.0 mf. 900 v. argon 2 cm.
Blanks (2)?

f. 5.6 3 or 4 —. one a double jimp.
2 Blanks.

f 11.3 3 pict.
1 Blanks.

f 23.0 3.

Suppose weak on f 23 but ok on others for the white face.

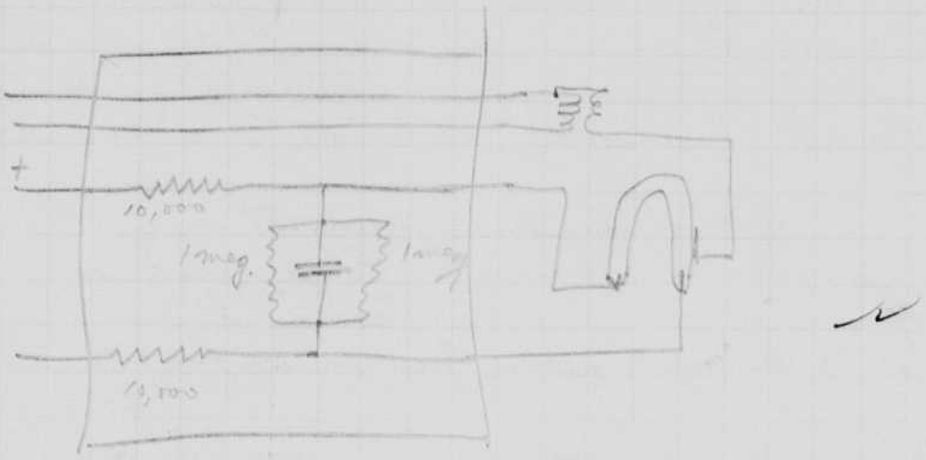
May 27 1936.

[illegible] Experiments.

Last class today. 6.027.

Sing a picture apparatus 30 mf
Cornell Dublier cat no KG 3300 17.85 list
(3½) x 3¾ x 4 9/16.

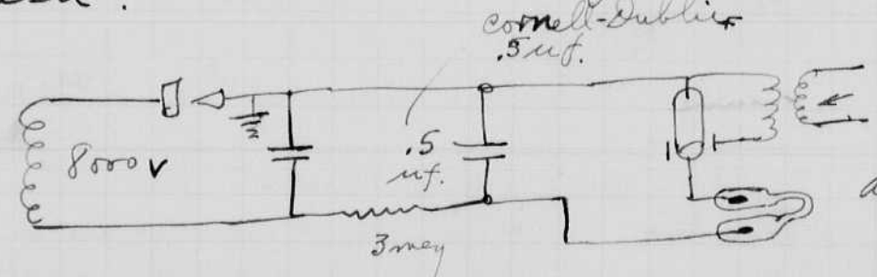
Suggested circuit



5 x 5 x 6 high box.

May 28, 1936.

Photostager or Drum camera 1 ft Diam.
Experiments with argon lamps single flash.



Film 1. 1800 R.P.M. f16. Several flashes. Kos. Rec. film.

2. 3500 - 4000 f16.

3 3500 - 3900 f16 Cap .008 mf. argon lamps.

4 3700 - 4000 f16 .008 mf Hg. 3mm th

Comparison tests. Argon 60 cm vs Mercury. ½ atm? + 3 mm He.

Capacity .008 mf. Hg control lamps per page 14. Same camera f 5.5 Lamps 18" from triplett meter. Camera 18" ± argon.

frames flashes.

Film 5

1
1
2
2
3
3
(0) time for 3 flashes
6
6.

Dev 3 min

Film 6

1
1
2
2
3
3
(0)
Joined 3 + frames lost.
6
6
Blank.
1
1
2
2
3
3
6
6

Dev 4½ min

Exposures about repeated on same film.

Film 7 Hg first 1 2 3 6 12 blank.
8 then argon 1 2 3 6 12 →

Dev. together 5 minutes in dilute D 72.

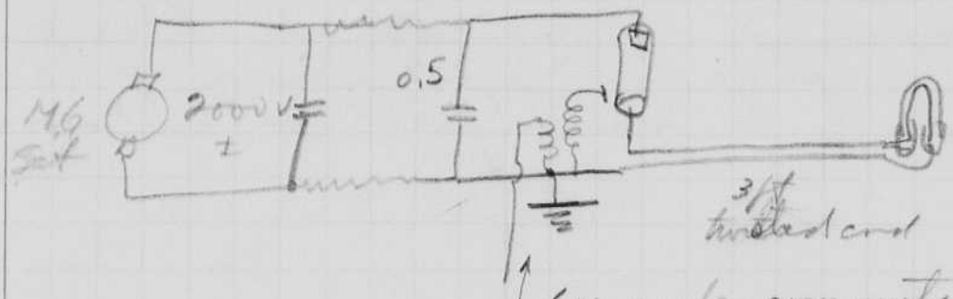
Density of argon exposures are several times ~~greater~~ than Hg.

Repeat experiment with neg. (background Eastman)
9 1 2 4 8 16 flashes argon first on film. Hg heater current in cryogel to 3 amps and then some to heat it. Density about same for each.

May 30 1936
H. E. Edgerton

Continuation of Experiments with Argon Lamp.

Connections as follows were tried.



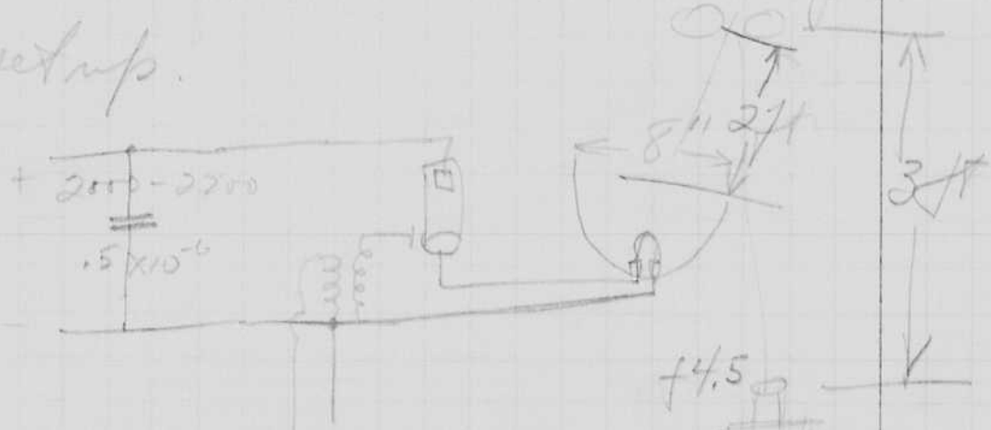
June 10 f 6.3 Positive film gives exposure.
" f 4.5 " " " Capacity 1/4 mf.

.25 x 800 x 10⁻⁶
.20 1200
.125 1600

May 31 1936.

Grier and I took pictures of Mallinckrodt Shaker today at about 200 pictures per second. The shaker operated at 270 r.p.m. in 100 cc of ether in a test tube and 4 strips of iron. Shaker started about 2:30 PM

Data on setup.



Regular negative film
DK 76 Developer 20 min development.

CE² = .25 x 2000 x 800 x 10⁻⁶ = 1 joule per picture f 4.5
1000 pictures = 1000 watts. 500 into tube.

Notebook # 7

Filming and Separation Record

___ unmounted photograph(s)

3 ? negative strip(s) inside mounted envelope pg. 17

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

was/were filmed where originally located between page 16 and 17.

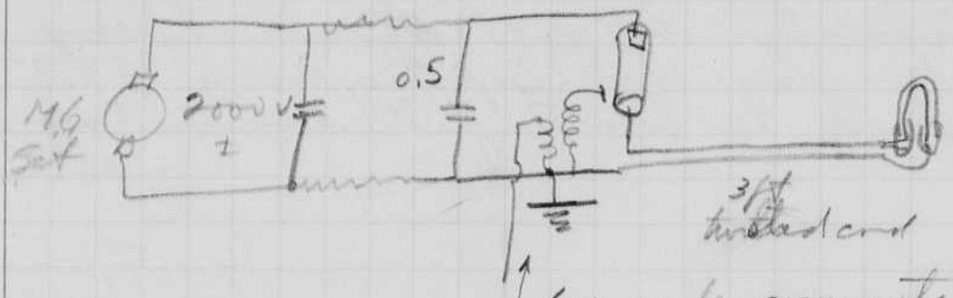
Item(s) now housed in accompanying folder.

Brodie California [illegible] Twiliger "Pittsfield" [illegible] Frazier.

May 30 1936
H. E. Edgerton

Continuation of Experiments with Argon Lamps.

Connections as follows were tried.

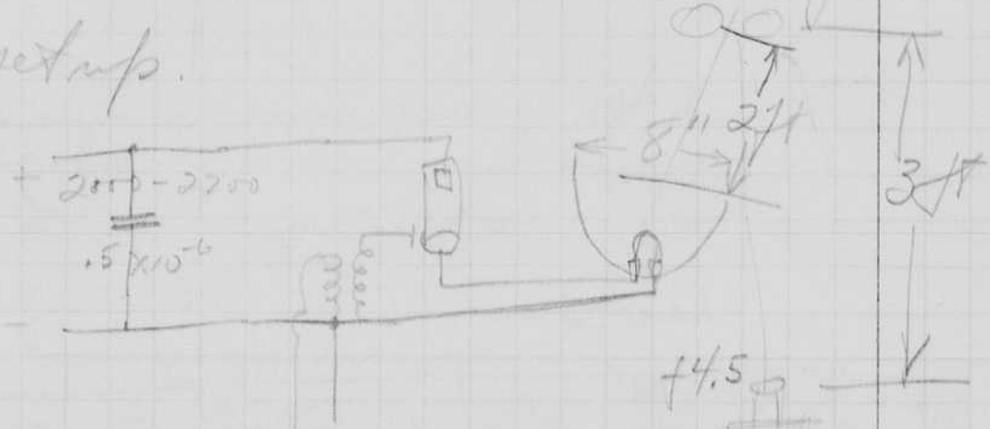


600 cycle commutator used.

Film No f 6.3 Positive film gives exposure.
" f 4.5 " " " Capacity 1/4 mf.

May 31 1936.

Sprit and broke pictures of Mallinckrodt Shaker today at about 200 pictures per second. The shaker operated at 220 r.p.m. 100 cc of ether in each and 4 strips of iron. Shaker started about 2:30 pm Date on setup.



Regular negative film
DK 76 Developer 20 min development.

CE² = .25 x 2000 x 2000 x10⁻⁶ = 1 joule per picture f4.5
1000 pictures = 1000 watts. 500 into tube.

Notebook # 7

Filming and Separation Record

____ unmounted photograph(s)

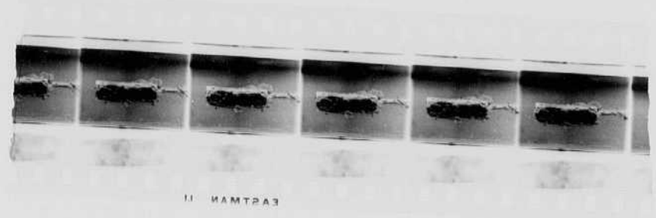
3 ? negative strip(s) inside mounted envelope pg. 17

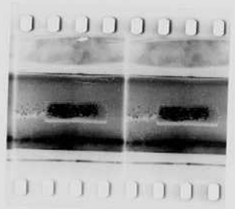
____ unmounted page(s)
(notes, drawings, letters, etc.)

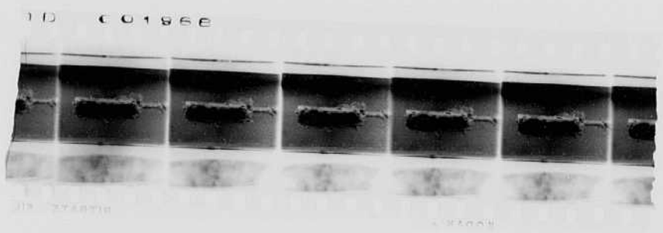
was/were filmed where originally located between page 16 and 17.

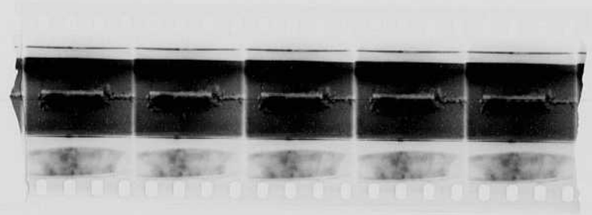
Item(s) now housed in accompanying folder.

Brooke California [illegible] Twilight [illegible] "Pittsfield" [illegible] Frazier.









June 2 1936
H.E. Edgerton.

Pumped a quartz tube (Germeshausen type) and filled with Argon 60 cm.

Worked with Javarine in a.m. and evening taking motion pictures of quenching steel in oil. Neg. filed f 3.2 D/72 20 min dev 75°.

300 ft taken in three pieces showing start, middle and end of quenching cycle.

100 ft taken of steel into hot water.

Brodie California

Chas Kingsley Twilliger Boyajian "Pittsfield" S.S. Dick Frazier.

June 21 1936
Stockholm.

Pumped a quartz tube (Germershausen type) and filled with argon 60 cm.

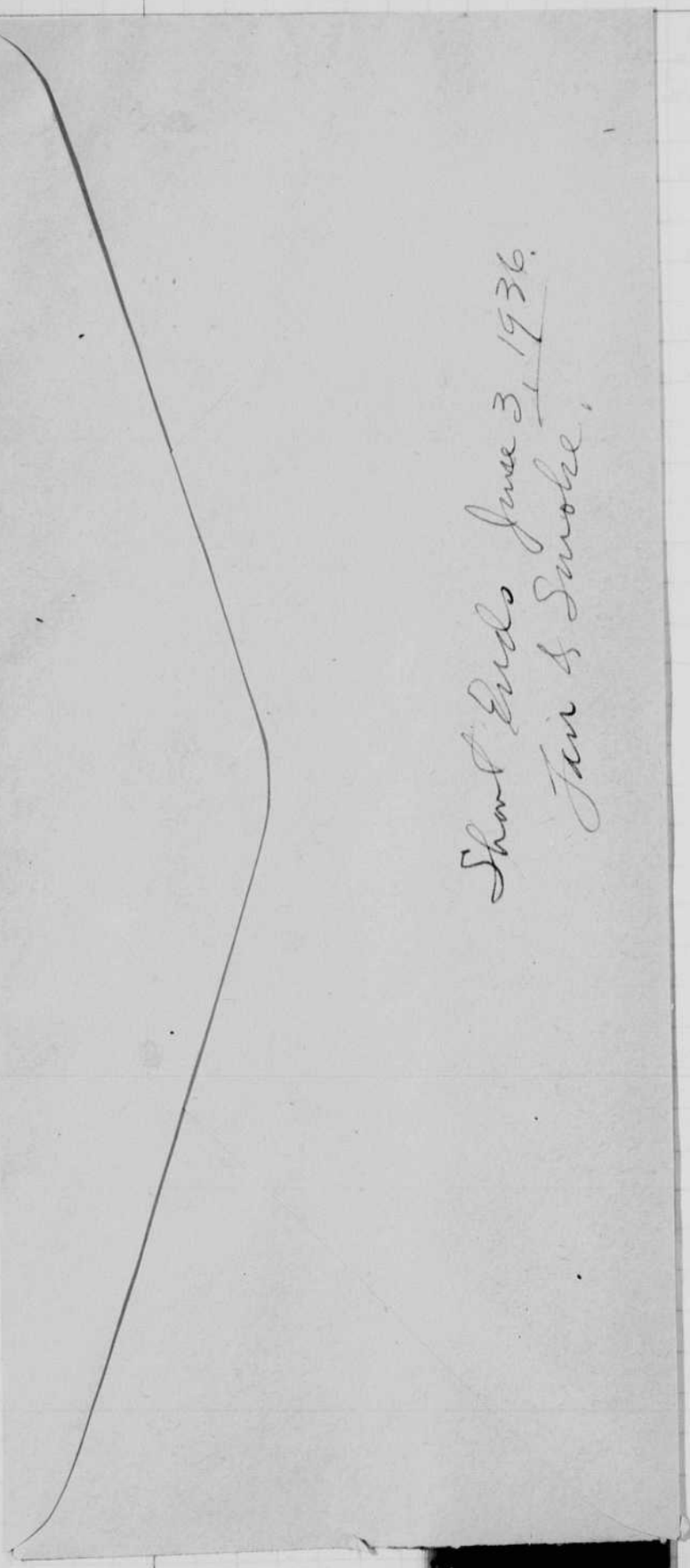
Worked with Javarine in a.m. and evening taking motion pictures of quenching steel in oil. Neg. filter f 3.2 D/72 20 min dev 75°.

300 ft taken in three pieces showing start, middle and end of quenching cycle.

100 ft taken of steel into hot water.

Brode California

Chas Kingsley Twilliger Boyajian "Pittsfield" S.S. Dick Frazier.



Shot 4' Ends June 3 1936.
Fair & Smoke.

June 4 — Movies of smoke through jaws for the D.E. Co.
& Peters of aeronautic. department.
800 ft taken.

June 5. Developed movie taken yesterday and also shot 600 ft of positive of the breaking of limestone for Briggs of Harvard.

June 6. Helped Herb with motion co Grinder job.
28cm argon lamp made & filling.

Notebook # 7

Filming and Separation Record

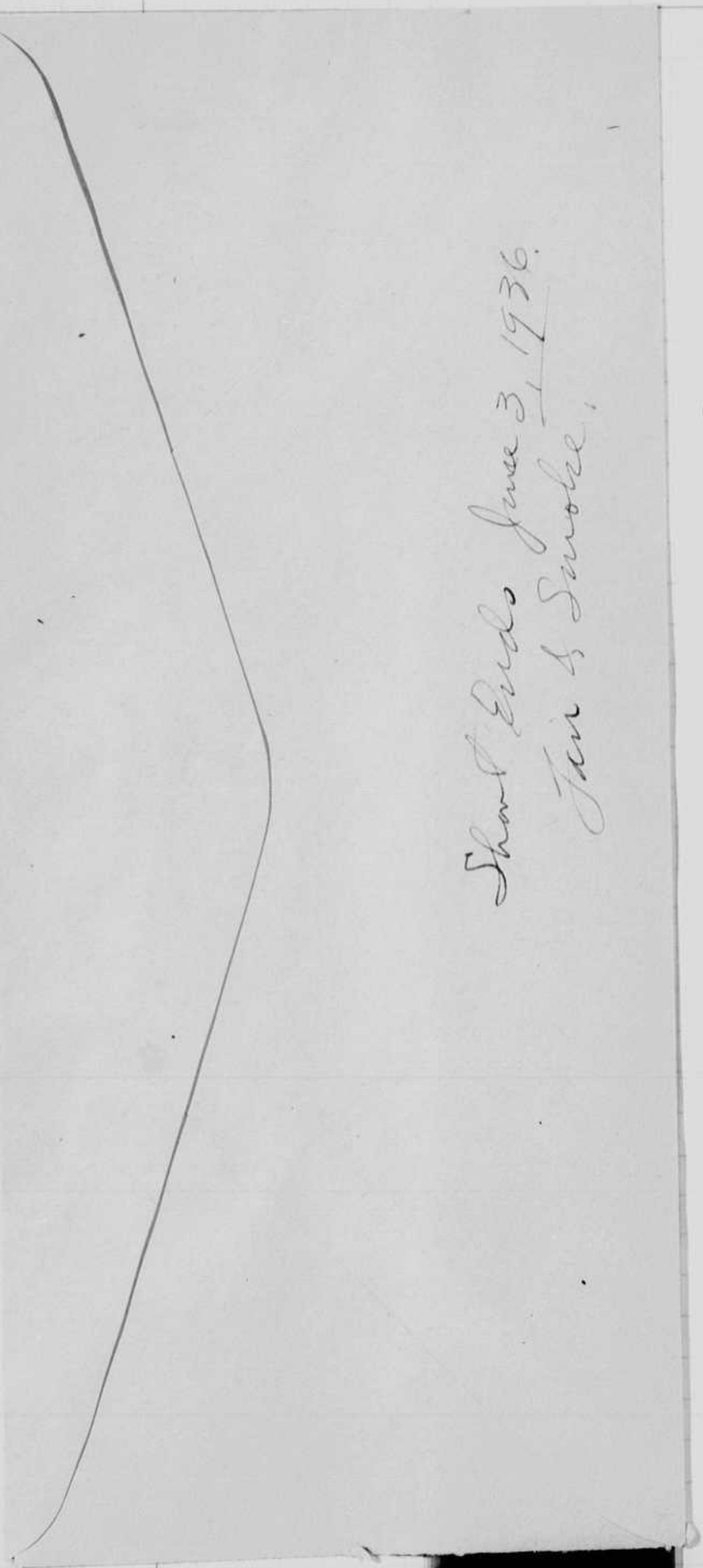
____ unmounted photograph(s)

11 ? negative strip(s) inside mounted envelope Pg 18

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

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

Item(s) now housed in accompanying folder.



Short Ends June 3, 1936.
Fair & Smoke.

June 4 — Movies of
Smoke through jaws
for the D.E. Co.
& Peters of aeronautic.
department.
800 ft taken.

June 5. Developed movie
taken yesterday and
also shot 600 ft
of pos film of the
breaking of mine stone
for Briggs of Harvard.

June 6. Helped Herb
with motion co Grinder
job.
28 cm argon lamp
made capillary.

Notebook # 7

Filming and Separation Record

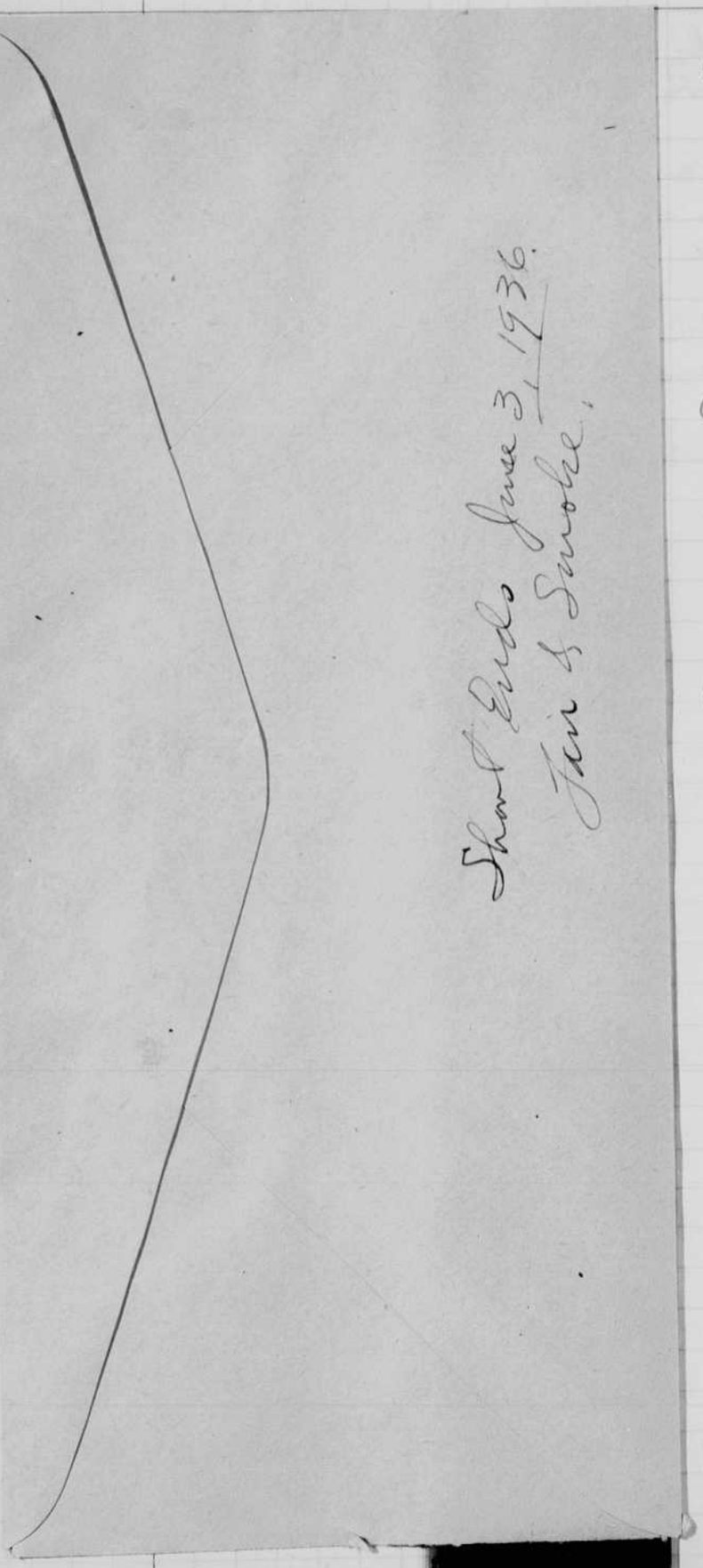
____ unmounted photograph(s)

11 ? negative strip(s) inside mounted envelope Pg 18

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

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

Item(s) now housed in accompanying folder.



Short Ends June 3, 1936.
Fair & Smoke.

June 4 – Movies of smoke through jars for the D.E. Co.
H Peters of aeronautics department.
800 ft taken.

June 5. Developed movies taken yesterday and also shot 600 ft of pos film of the breaking of lung stone for Briggs of Harvard.

June 6. Helped Herb with motion co Grinder job.
28 cm argon lamp made 2 pilings.

Notebook # 7

Filming and Separation Record

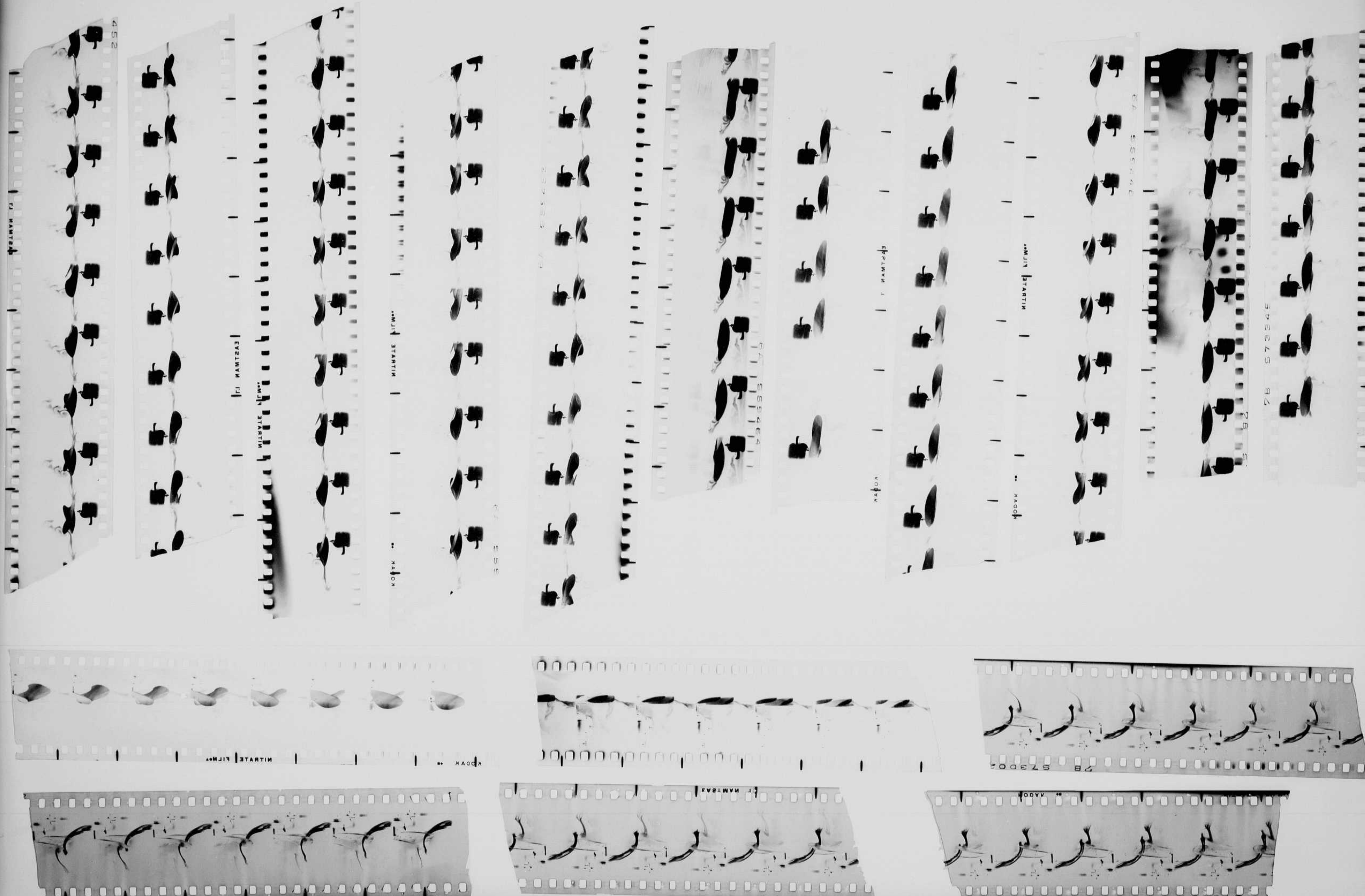
____ unmounted photograph(s)

11 ? negative strip(s) inside mounted envelope Pg 18

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

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

Item(s) now housed in accompanying folder.



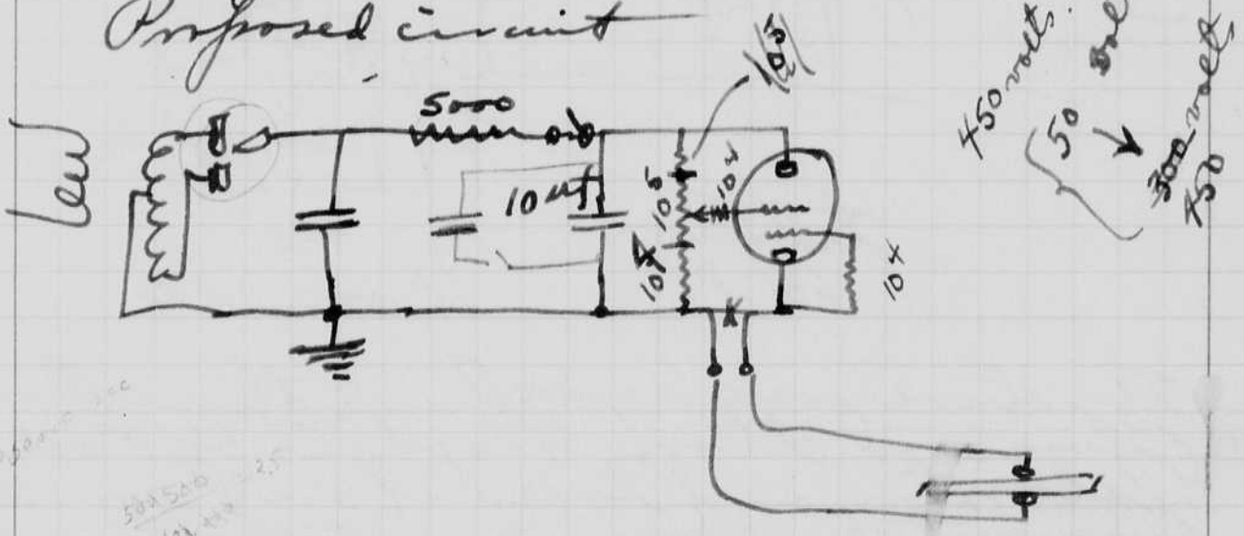
June 11. 1936.

Taking more pictures of jaws with smoke for Peters (Gen'l Electric) Records in separate note book.

Discussed with Germeshausen and DeForest Eglin and Walsh the use of the stroboscopic lamp for finding cracks in ~~metals~~ steel parts. A large unidirectional current is set up to build magnetize the material. Dust is used to show up the cracks.

DeForest asked us to build him one out of it to accomplish this. I called P. Bliss, a junior, and he is coming in Monday to start.

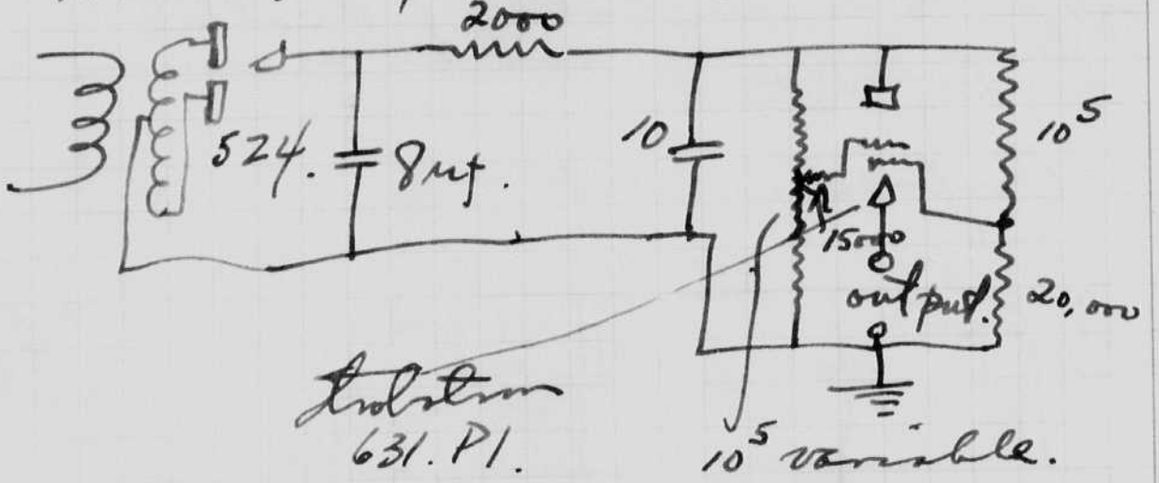
Proposed circuit



June 17 1936
Washington.

Returned last night from trip to Summit N.J. to visit my sister and to see Mr. John Long and Mr. Depke at the Bethlehem steel co. While there at the Bell Steel on Tuesday at 2:30 I showed movies and talked for about an hour to some fifty men from the laboratory and plant. Esther and two children Mary Lou and William went to Summit for the trip.

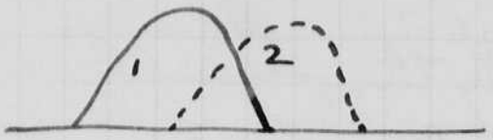
Mr. R. Bliss is wiring up a stabilizing apparatus for trial by Dr. Forest. Wiring diagram below.



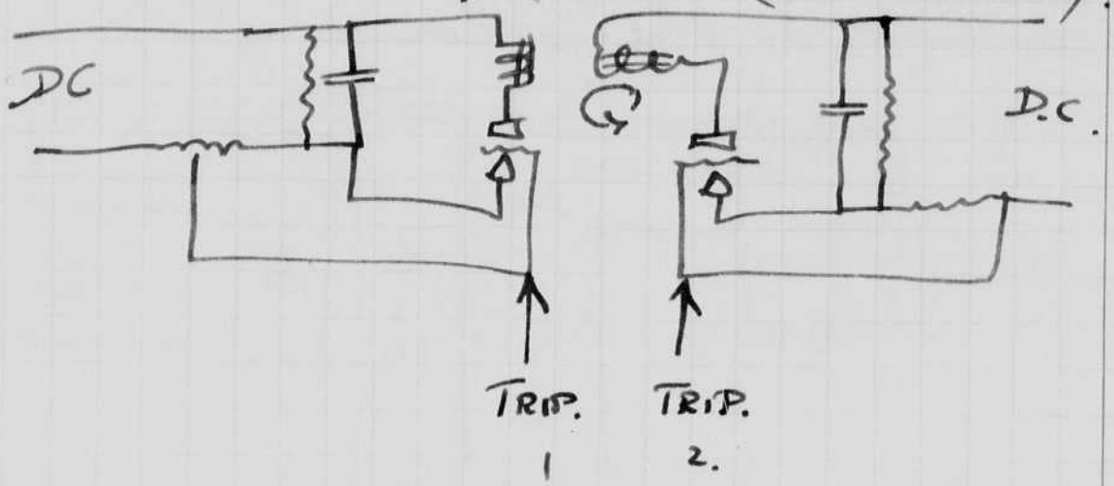
The above was wired up this afternoon Bliss and I took it over to the Forest laboratory and tried it out on some magnetic specimens that were there. It worked satisfactory. tomorrow Bliss is going to make a box and cables for the apparatus.

Borden was in this afternoon and we discussed inverter circuit for use in Hardy's color analyzer. I suggested the use of two single thyratrons to produce pulses of current to start the motor instead of the use of a.c. two pulses 180 degrees apart should give a rotation and the direction should be

determined by the ~~direction~~ relative firing time of the tubes.



2ϕ. motor (Induction).



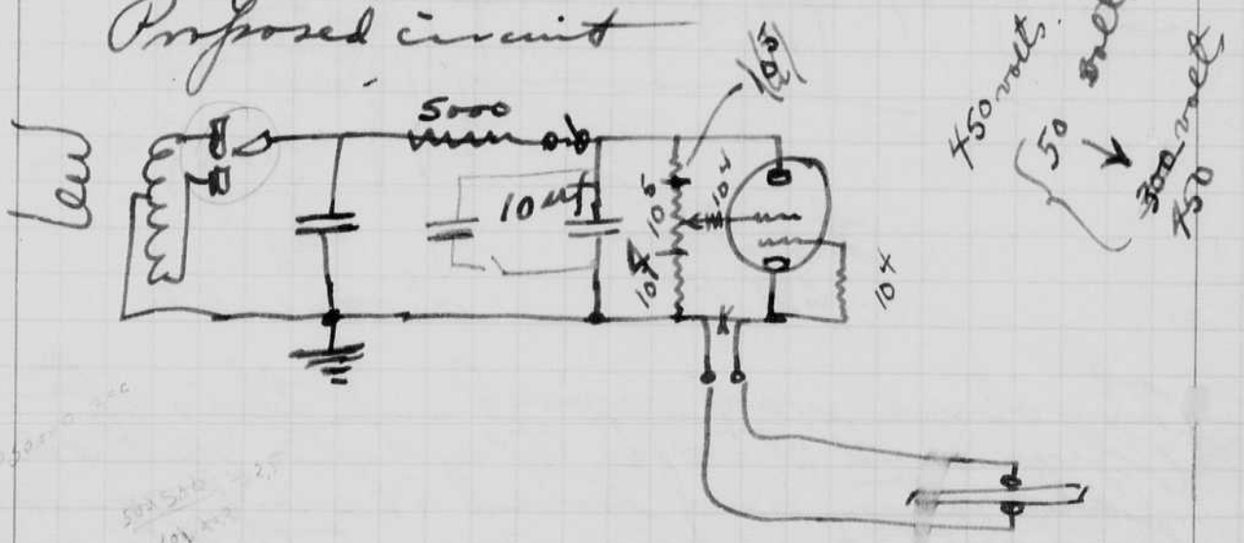
June 11. 1936.

Taking more pictures of jaws with smoke for Peters (Prof General Electric) Records in separate note book.

Discussed with Germeshausen and ~~DeForest~~ Eglin and Walsh the use of the strobotac lamp for finding cracks in ~~metal~~ steel parts. A large unidirectional current is set up to magnetize the material. Dust is used to show up the cracks.

DeForest asked us to build him one ~~of~~ to accomplish this. I called P. Bliss, a jumper, and he is coming in Monday to start.

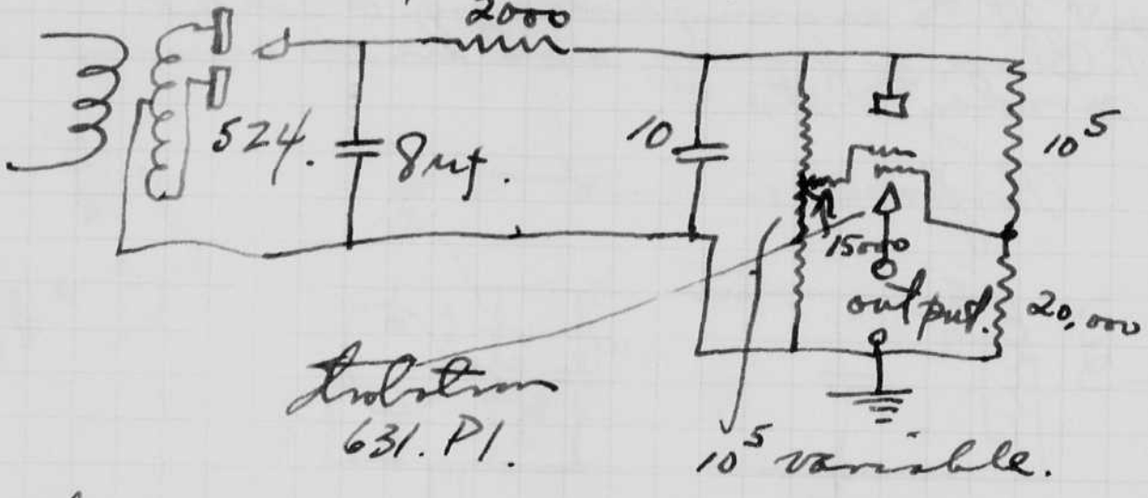
Proposed circuit



June 17 1936
Delegates.

Returned last night from trip to Summit N.J. to visit my sister and to see Mr John Long and other people at the Bethlehem steel co. While there at the Bell Steel on Tuesday at 2:30 I showed movies and talked for about an hour to some fifty men from the laboratory and plant. Father and two fellow Masons and Willian went to Summit for the trip.

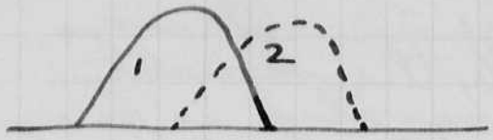
Mr. P. Bliss is wiring up a stroboscopic apparatus for trial by Prof. De Forest. Wiring diagram below.



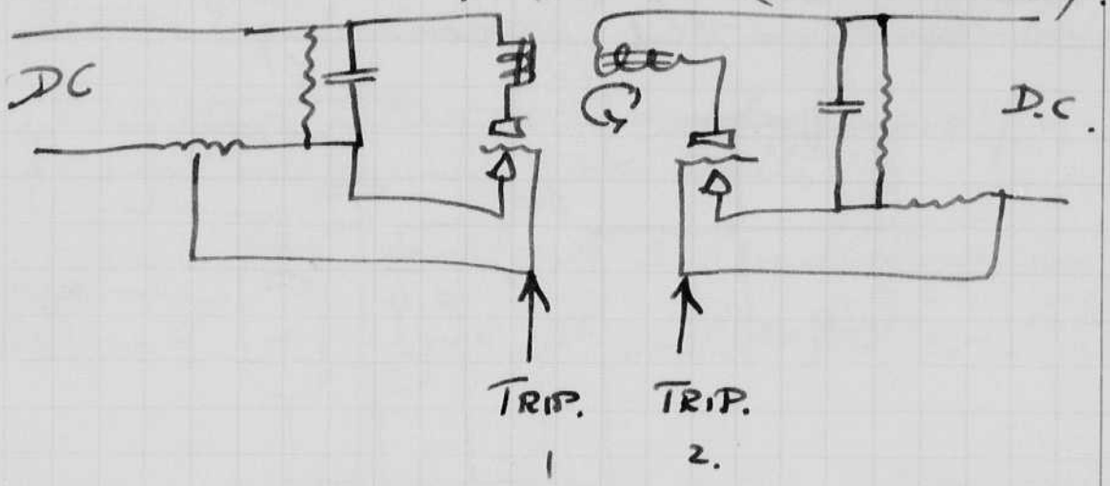
The above was wired up this afternoon Bliss and I took it over to De Forest laboratory and tried it out on some magnetic specimens that were there. It worked satisfactory. Tomorrow Bliss is going to make a box and cables for the apparatus.

Barstow was in this afternoon and we discussed inverter circuit for use in Hardy's color analyzer. I suggested the use of two single thyratrons to produce pulses 180 degrees apart instead of the use of a.c. two pulses would give a rotation and the direction should be

determined by the ~~direction~~ relative firing times of the tubes.



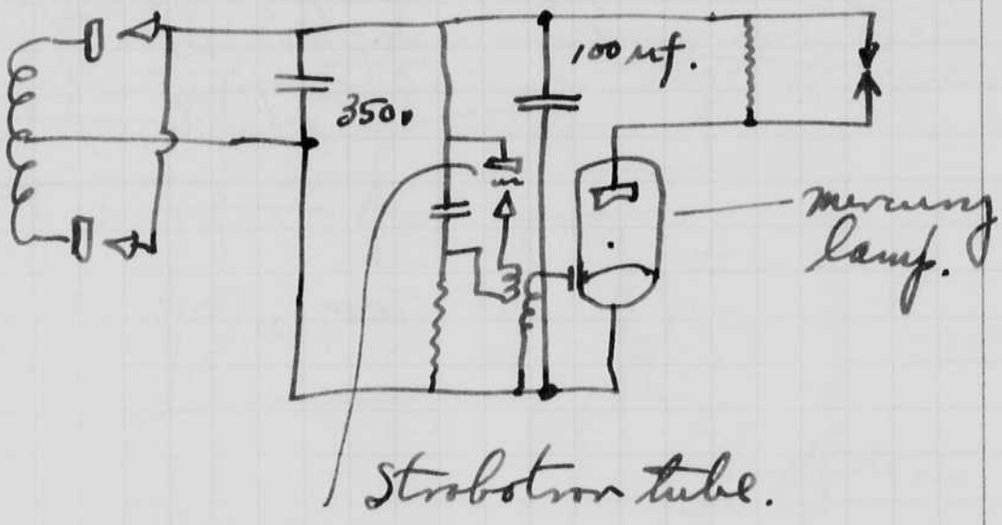
2 ϕ. motor (Induction).



June 18 1936

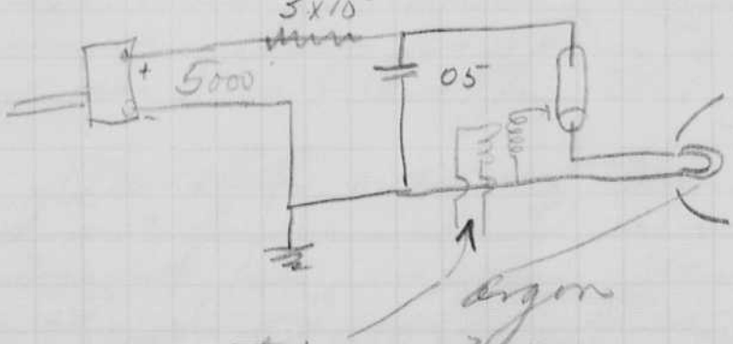
Prof Defrost was in this morning and we again tried out the apparatus described on page 22. He was very pleased with the results.

A larger apparatus is desired and we were asked to build up one for trial. The contemplated circuit is the following.



June 19. '36.

Last night I worked with Irvin on the apparatus for taking photographs of bullets by reflected light. The conditions were as below.



We had trouble with the amplifier that Abbot built last term. Worked home at 9.30. Continued experiments today and

found that the coupling condenser between the first and second stage was open circuited. This is C, on page 7. on first tube. The back coupling circuit was removed as I do not believe it to be needed.

June 20 36 Continued experiments with Reflected light photos of 22 long rifle bulletts.

1. One shot taken with Sept. camera f 3.5. 0.05 mf capacity 8000 volts ?±
   Focus bad. about 3:1 reduction on film.
2. Repeat. above but with better lineups.
3. Changed capacity to 0.5 mf. 8000 volt.
   Changed to ~~16 x 9 cm~~ 9x12 cm camera.
   Photos at ~~f~~ 5.6 on
   Wood ~~penetrated~~ by bullet
4. Same with less ~~oxygenation~~
   Rubber strip to be penetrated by bullet.

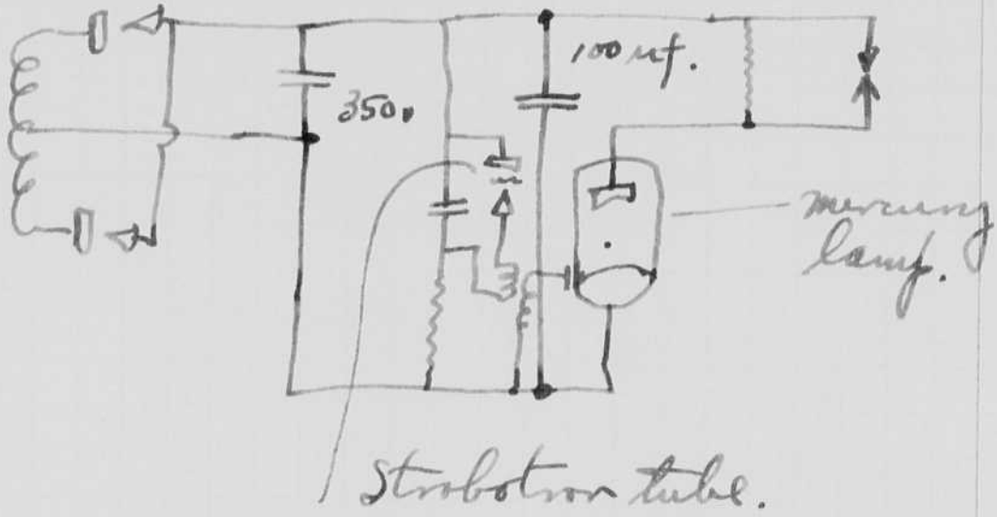
Robert

Bill

June 18 1936
Bridgeport Conn

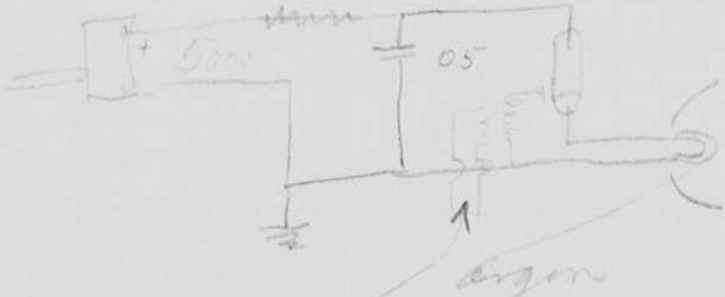
Prof DeForest was in this morning and we again tried out the apparatus described on page 22. He was very pleased with the result.

A larger apparatus is desired and we were asked to build up one for trial. The contemplated circuit is the following.



June 19. 36.

Last night I worked with Irving on the apparatus for flying pictures by projected light. The circuit was as follows.



trip

We had trouble with the amplifier that about quit last term. Worked from 9 to 9.30. Continued experiments today and

found that the coupling condenser between the first and second stage was open circuited. Fig as C, on page 7. Tube removed as I don't intend it to be needed.

June 20, 36 Continued experiments with Reflected light photos of 22 long rifle bullets.

1. One shot taken with Sept. camera f 3.5. 0.05 mf capacity 8000 volts ?±
   Focus bad. about 3:1 reduction on film.
2. Repeat. above but with better lineups.
3. Charged capacity to 0.5 mf. 8000 volts.
   Changed to ~~16 x 9 cm~~ 9x12 cm camera.
   Photos at f 5.6 on
   Wood penetrated by bullet
4. Same with less magnification.
   Rubber strip to be penetrated by bullet.

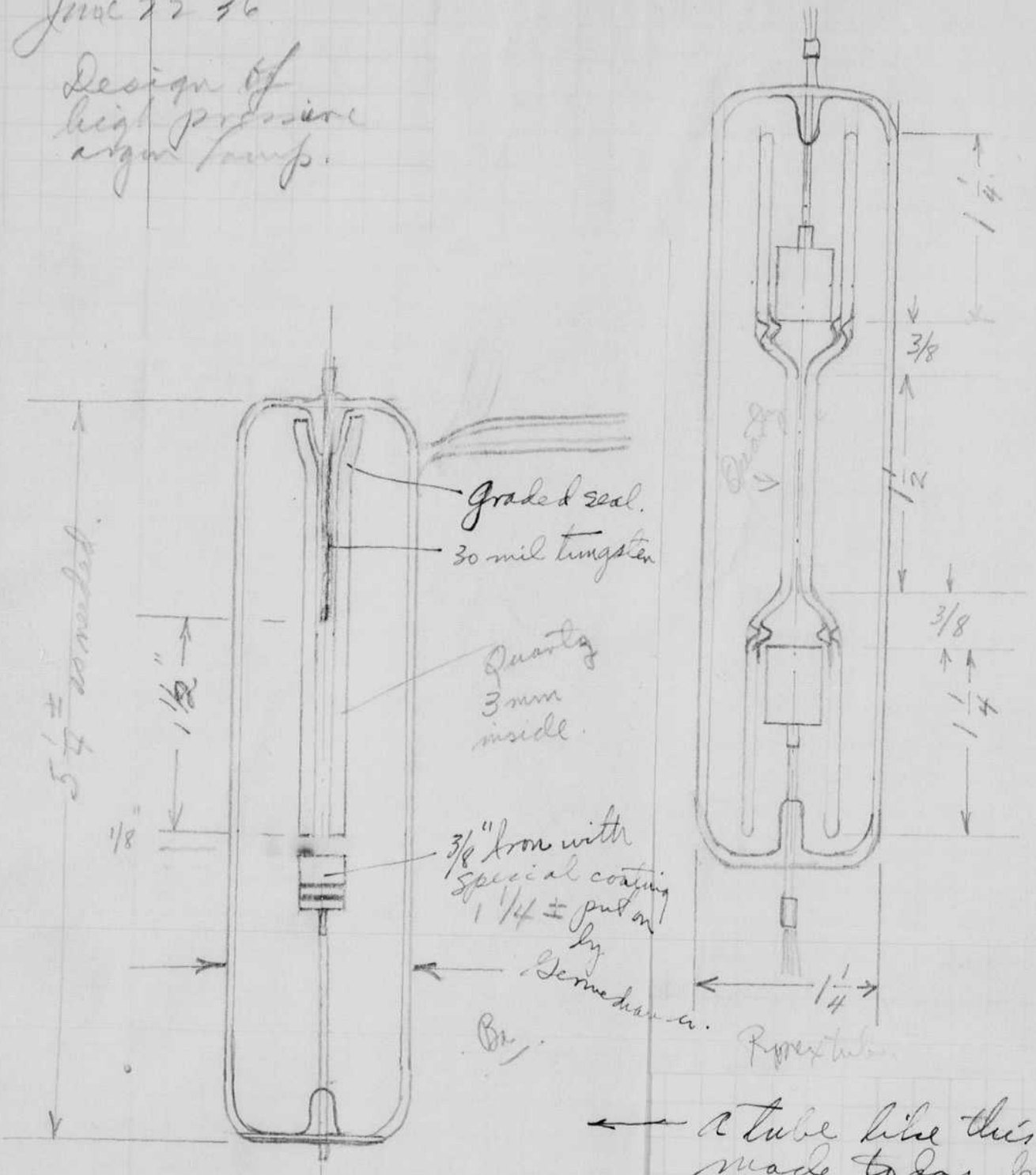
many tries

Robert

Bill

June 22 36

Design of high pressure argon lamp.



← A tube like this was made today by Mr. Waymouth.

A. Baked 1 hour 400° C±.
B. Bombarded 10 min ±.
C. Filled with argon at atmospheric pressure and run with 2 mf 3500 Ω 1400 volts also 1/2 mf.
D. Pumped out and filled with argon 20 cm.

GENERAL RADIO COMPANY

TYPE 631-P1 STROBOTRON
(Neon-Filled)

Main Use	Stroboscopic Light or Relay
Number of Electrodes	4
Cathode Type	Cold Cathode with Cathode Spot

Typical Load Characteristics

Anode Voltage (max)	350
Anode Voltage (min)	110
Maximum Inverse Anode Voltage	350
*Average Anode Current Milliamperes (max)	50 to 100
**Instantaneous Anode Current Amperes (max)	250
***Instantaneous Anode Current Amperes (min)	5 approximately
Average Tube Drop, Volts	
Glow Discharge	75
Arc Discharge	20 approximately

Typical Starting Characteristics

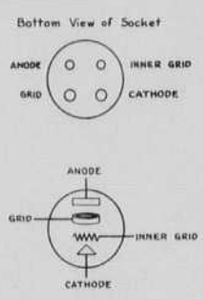
The Strobotron is started by causing a glow discharge between the grids. Either grid may be used as a control grid, the other grid being appropriately biased.

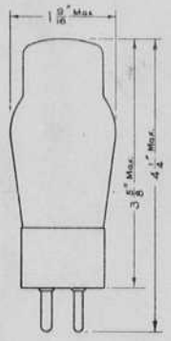
With Inner Grid at Cathode Potential

Starting Voltage, Grid Positive	110 to 120
Starting Voltage, Grid Negative	115 to 125
Grid Current Milliamperes (max)	1

* Rating is determined by heating and varies with peak and duty cycle.
** Surge obtained from condenser discharge, up to 12 mfd. at 250 volts.
*** Minimum current required to start cathode spot.

Socket Connections

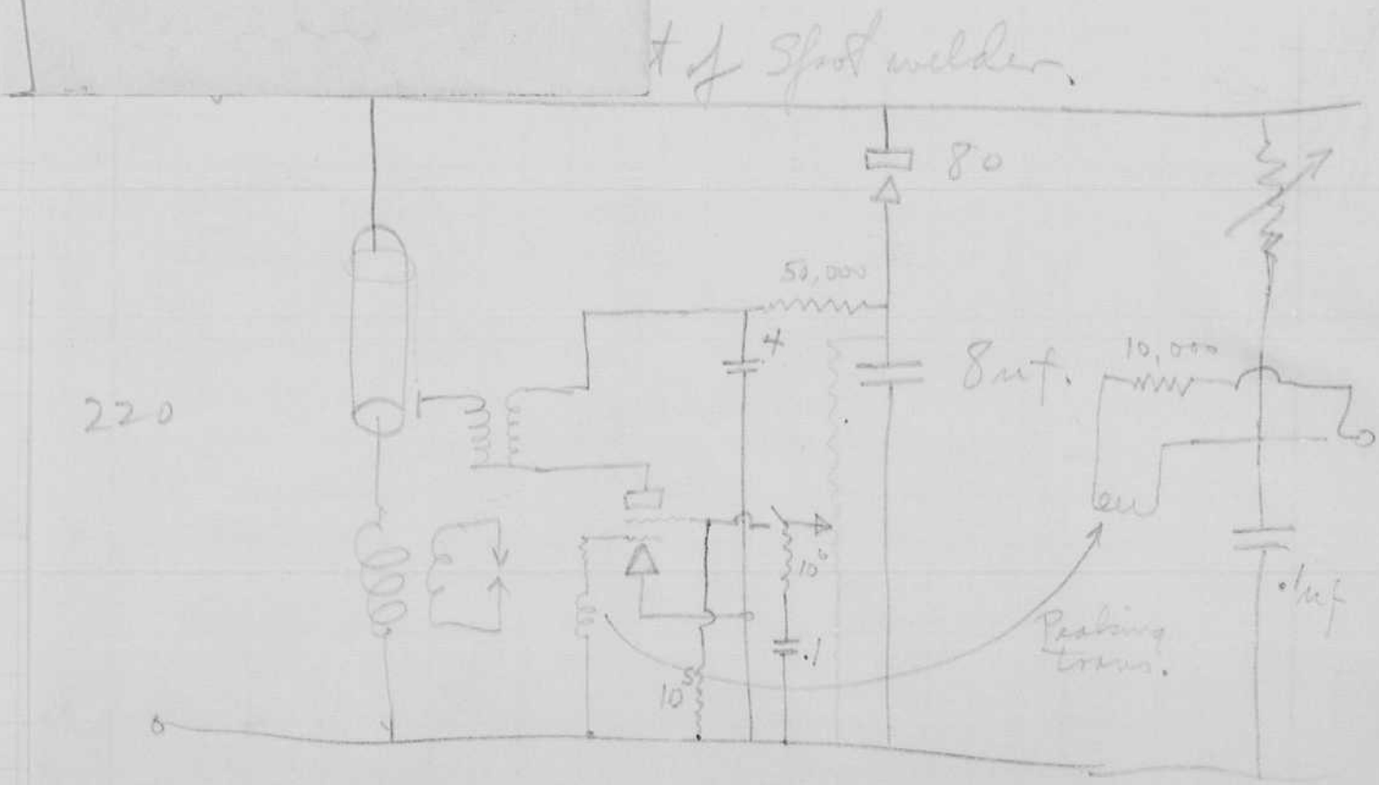




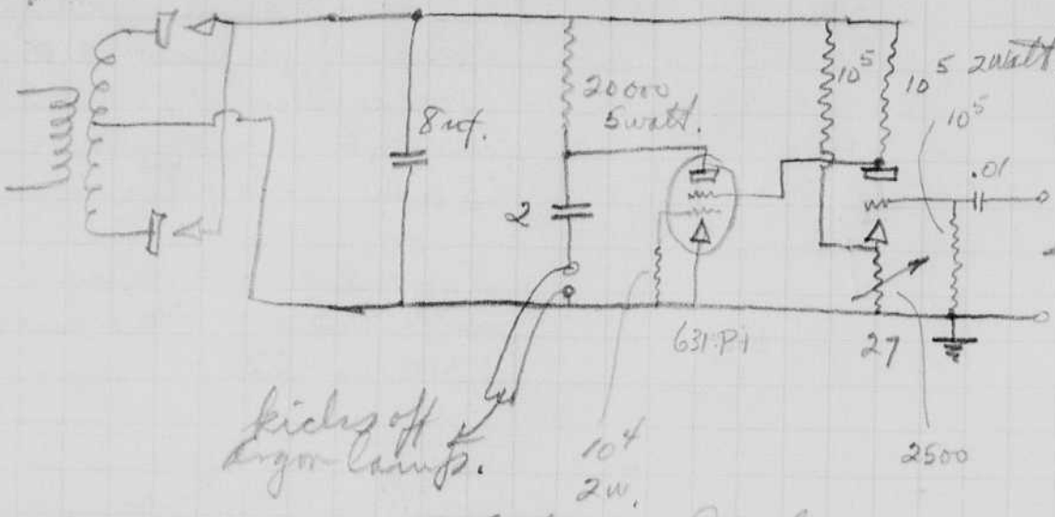
Form 427-A

The lamp shown on the preceding page runs ok at 1200 cycles 1½ mf. 400 ohms. charging resistor on the 3 kw outfit.

It holds over when run with 0.5 mf 800 ohms at 2500 volts.



June 24, 1936
H. E. Edgerton.



Circuit suggested to Dick Evans for use in the knee sorting machine in the Physics department.

June 24 cont'd. Yesterday Bliss finished the temporary setup (to be) of page 22) and tested it. He used 20 microfarads of capacity. The E.R. tests showed 1300 amps peak. A five foot lead (concentric cable) showed no decrease in the peak current. This means that all the inductance is in the condensers.

We have ordered some new condensers from the Cornell Dublier co which should be here soon. They will have less internal inductance, we hope.

Prof Defrenza was in this morning and asked for two more units same as shown on page 20.

Dick Taylor was down and I gave him two stroboscopes for experimental use on the new Integraph.

Swinish came in and I gave him two stroboscopes. He is going to Missouri University next year to be a Prof. in the Physics Dept.

I worked with Davarine all afternoon taking movies of sounding 1/200 sec 1200 volts (3 kw) 1.25 mf. 400 lumens per sq ft of 3.2 neg film Bond & H2O.

Alvin Blake

(1)

(1) $R = .07\,\omega$ on speed control.

Δ = 1 cm to point where tube begins to oscillate very fast.

δ = 3 mm after this point.

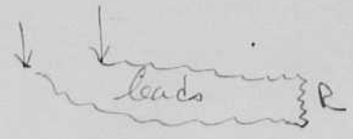
$V_\Delta = 58$ } on cathode ray tube.

$V_\delta = 18$

$I_\Delta = 830$ amps slow

$I_\delta = 260$ amps fast.

(2)



Concentric cable.
about 5 ft long.

$R = .07$

Δ = 7 mm

δ = 2 mm

$V_\Delta = 42$

$V_\delta = 12$

$I_\Delta = 600$ amps

$I_\delta = 170$ amps

Other conditions same as above.

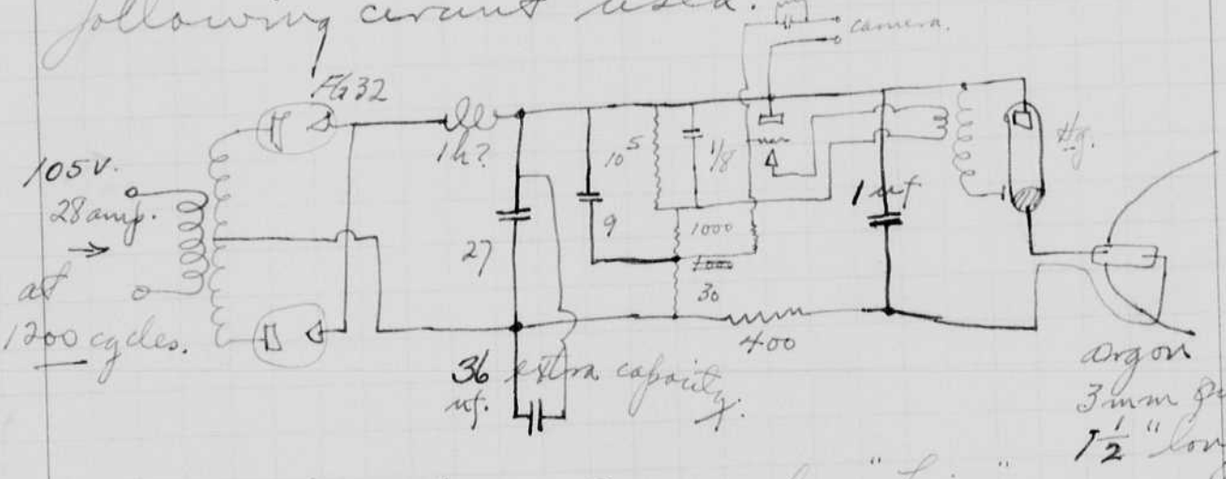
June 22 1936
Measured by
Philip Bliss

July 2 1936

H. E. Edgerton.

The high-current surge generator described on page 20 and built by Bliss for Defreest was given to him last week and he at once sent it to Chicago for use. Two more are being built and will be delivered next week. The last two are quite different than the first as far as appearance is concerned. The new ones will be in a wooden cabinet with a cover like a meter.

I spent considerable time last week getting ready for a trip to Mrs. Lawrence Webster's home in Holderness N. H. To take photographs of humming birds in action. The three kw outfit was taken and the following circuit used.



Camera lens at f 2 Summar lens "Leica".
Regular negative Par speed film.

For single pictures a 12 mf condenser was connected in parallel with the 1 mf condenser and the 400 ohm resistor increased to 4000 ohms.

Grier went with me on the trip and we shot about 1000 ft of film (35 mm) and 3½ dozen of 9x12 cm verichrome single photographs. We left N. Y. at 10 Monday morning and arrived there about 3. in the afternoon. Returned the next day. Mr. & Mrs. Webster entertained us royally.

I spent yesterday and today processing film. The stills were ok but the movies were

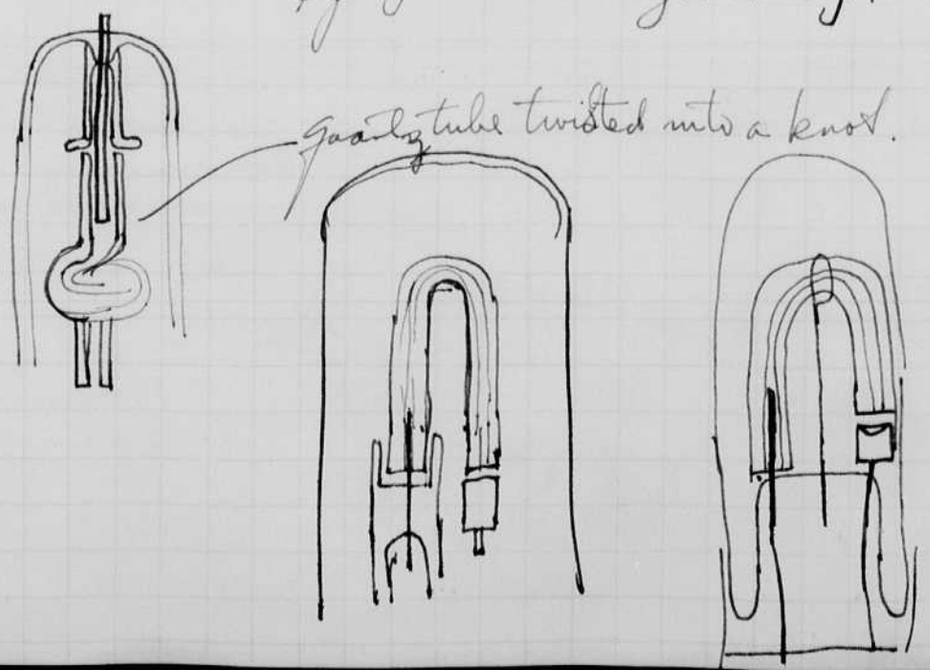
not very good. The movies taken outside were ~~pictures~~ ing due to the fact that the bird flew away too quick. The movies taken through the windows were dim and not in focus? If we go back again, a white back ground should be put back of the object being photographed. The feathers of the bird do not photograph very well.

Nottingham has been trying out the spot welder using a strobotron and a Hg tube. He is trying to get a multiple cycle welder as well as a controlled half cycle welder.

Dick Taylor was down discussing the use of strobotrons in the new differential analyzer. Gemmeshausen spent some time with him this afternoon going over the proposed circuits.

Javarine and I spent several hours together today editing the high speed motion pictures of steel quenched in water, oil, and in brine. He is going to write titles and complete the reel for showing next fall at the meeting of the metallurgy society.

High pressure argon lamp.

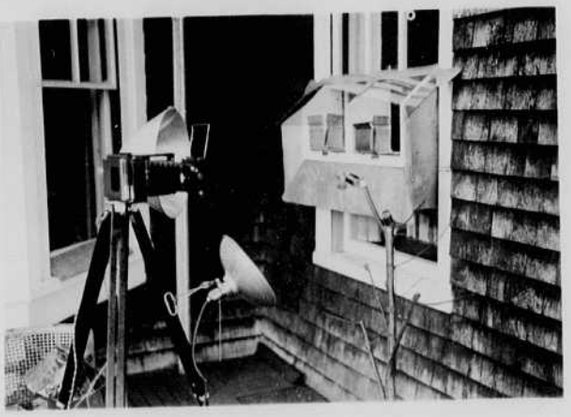


8.

July 10 1936
D & Edgerton

My father & mother were here from July 3 to today. My sister Mary Ellen and her two boys came also from Summit N.J. Dad and I spent Monday July 6 at the Acousti Products Co. taking Golf Pictures for Mr. Young. 61 photos taken

Herbert G. Drier with the apparatus that we took to Holderness N.H.



Set up for single photos note bird in center.

Mr. & Mrs. Lawrence Webster

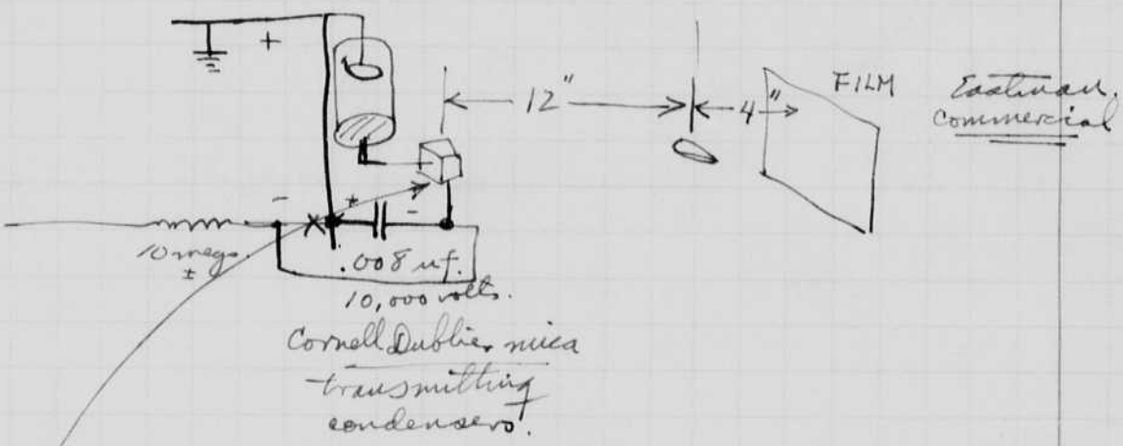
Mrs. Lawrence Webster with two humming birds.

July 11, 1936.

Herb Grier was married today to Winifred Davis.

Zerneshausen and Stook shadow spark photographs on July 9 in the evening. Regular .30 caliber service ammunition was used in a regular army rifle. Some of the photographs were taken with the bullet going through a #18 gage aluminum sheet.

The spark was timed with a rochelle salt piezo electric crystal energized by the sound wave that followed the bullet. The amplifier circuit is shown on page 7 and page 8 of this notebook. Other details are shown below.



Spark gap in a lava block. 1 mm hole or slightly less. aluminum wires for electrodes.

The negatives were thin. More capacity or more voltage should be used.

8.

July 10, 1936
At Edgerton

My father & mother were here from July 3 to today. My sister Mary Ellen and her two boys came also from Summit N.J.
Dad and I spent Monday July 6 at the Acousticon Co. taking Golf Pictures for Mr. Young.

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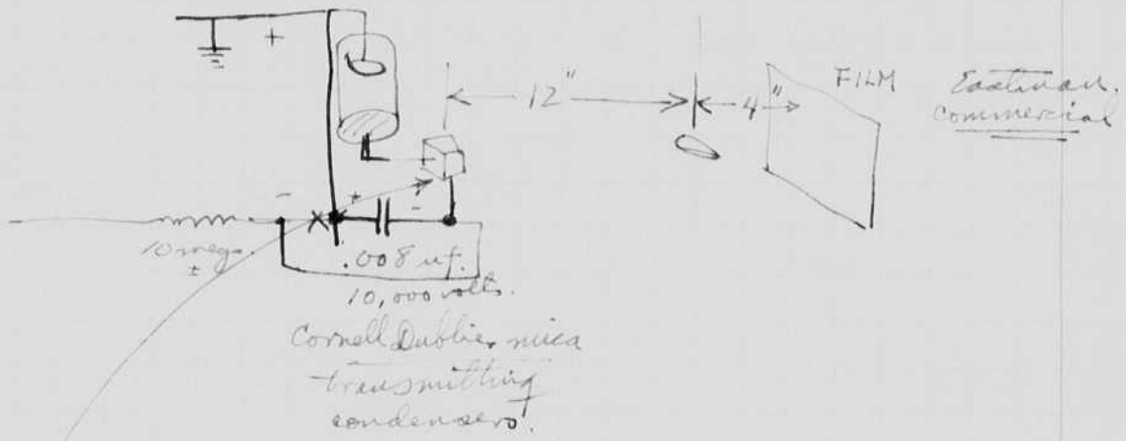


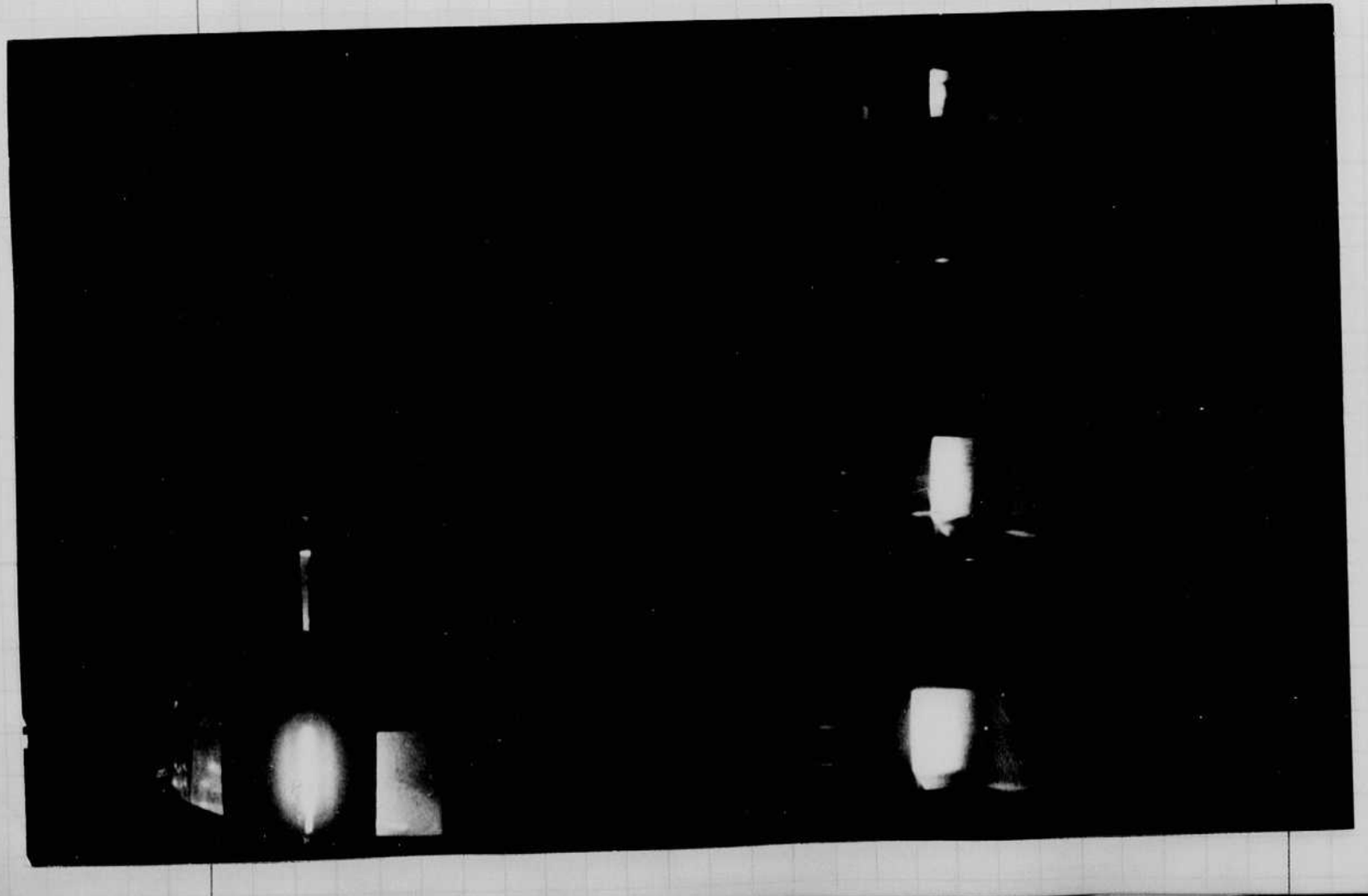
Spark gap in a lava block. 1 mm hole or slightly less. aluminum wires for electrodes.

The magnification is about 3 or more. Negative should be used.

July 12 1936
Edgerton.

Data from negatives of humming bird taken June 29-30 1936.

end of film	stroke	1/60 sec. = .0167 sec.		Time for beat	beats per sec.	
	7 frames	9 frames	turning.	.013 beat/sec.	77	
	10	11	turning.	.0152	66	
{	24	20	Hovering.	.02	50	female
{	21	18 1/2	"	.019	53	
{	19	16 1/2		.0192	52	
{	20	16 1/2	Hovering.	.02	50	female
{	19	16	"	.02	50	
{	17	15	"	.019	53	
{	17	14	"	.02+	50	
{	11	17	Turning	.011		male ?
{	13	16	"	.0135	74	
{	14	15.	Hovering	.0155	64	
{	13	14 1/2	"	.015	66	
{	12	13 1/2	"	.015	66	
{	12	12 1/2	"	.016	62	
{	10	12	Backing away	.0135	74	

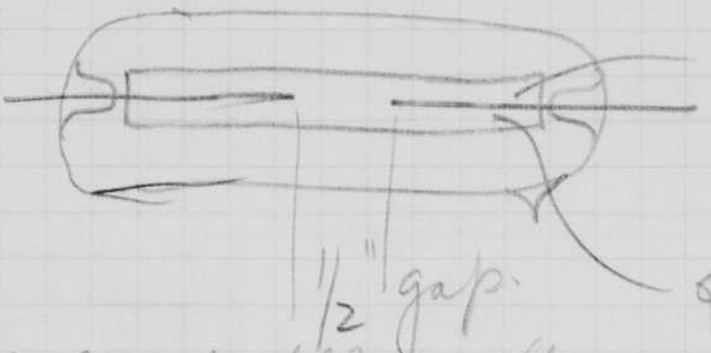


July 14 1936
Kleidograph.

Lecture at 8:15 this morning to Dr Hausers class in Colloidal Chemistry on Stroboscopic light and its uses.

Delivered two Stratton surges to De Forest for magnetic testing.

Built a tube today as per below.



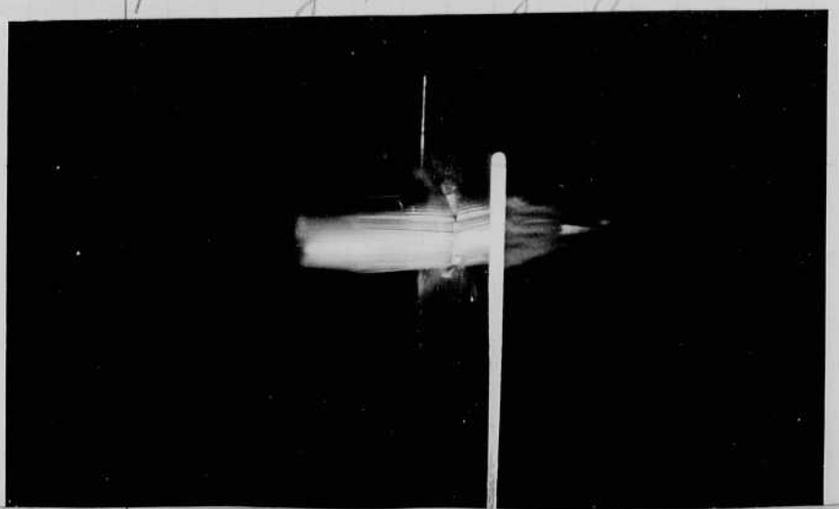
Baked and filled with argon at 1 atmosphere.

two photos f8 - f16. 1/2 sec exposure ok. 10,000 V.

July 15, 1936.

Germeshausen and I worked in evening taking .30 calibe (Service ammunition) bullets. Two or three shots to line up the camera and lights and piezo electric trip.

First picture taken at f8 showed bullet 1/2 way through plate. Copy below. Trailer shows frequency of discharge.



1/16" for 1/2 cycle.
assume 2700 ft./sec. = 32000"/sec.

$T = \frac{1/16}{32000} = 2 \times 10^{-6}$ seconds. ($\frac{1}{2}$ cyc.

$f = \frac{1}{4 \times 10^{-6}} = 250.$ KC.

The Hg tube is back firing Damping resistance is needed.

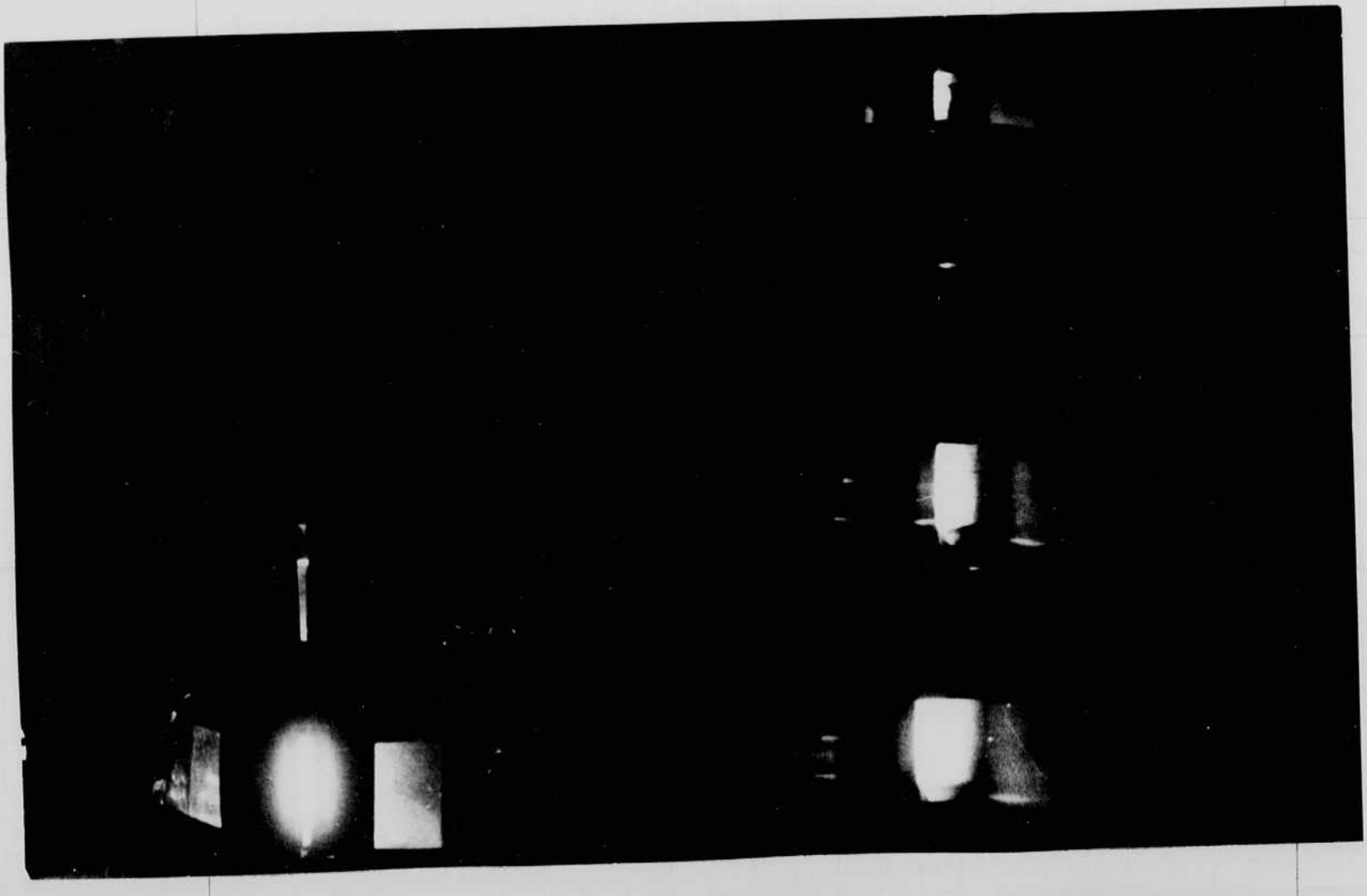
June 12 1936

Los Angeles.

Data for negatives of humming bird taken

June 25-30 1936.

stroke	1/60 sec. = .0167 sec.		time for beat	beat per m.
exposure	7 grams	9 grams		
10	11	Tail up.	.013 beat.	77.
24	20	Tail up.	.0152	66
21	18 1/2	"	.02 jewels	50
19	16 1/2	"	.019	53
19	16 1/2	"	.0192	52.
20	16 1/2	Tail up.	.02	50
19	16	"	.02	50
17	15	"	.019	53
17	14	"	.02+	50
11	17	Tail up.	.011	91
13	16	"	.0135	74
14	15.	Tail up.	.0155	64
13	14 1/2	"	.015	67
12	13 1/2	"	.015	67
12	12 1/2	"	.016	62
13	12	Tail up.	.013	74



July 14 1930

Kleidograph.

Lecture at 8 15 this morning to by Hansen's class in Colloidal Chemistry on Stroboscopic light and its uses.

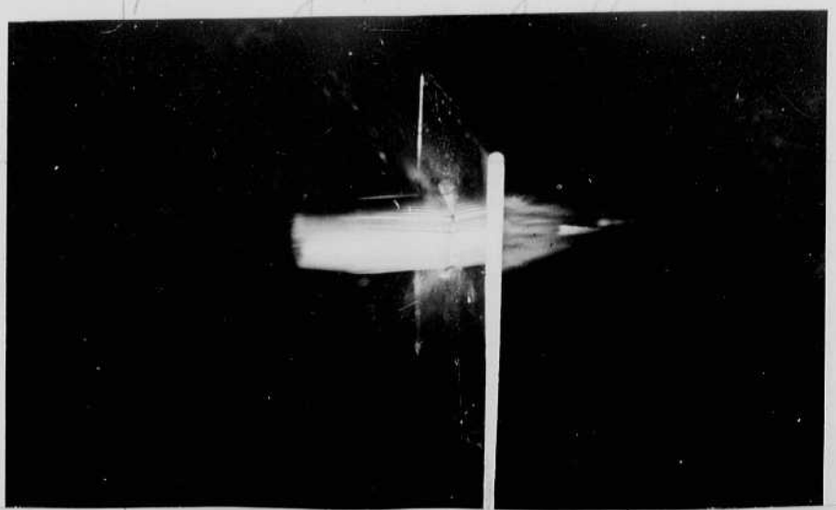
Received two Strutron surges to Du Forest for magnetic testing.

Built a tube today as per below.

Baked and filled with argon at 1 atmosphere.

Two shots f8 - f16. 1/2 μf 10,000 V.

July 15, 1930.



1/2 way through gate.

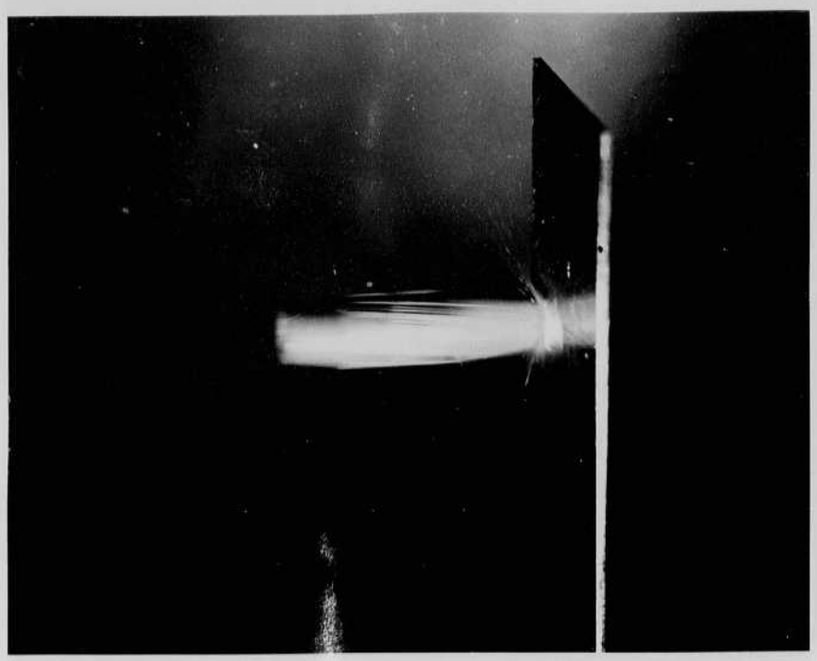
1/2 μf for 1/2 cycle.

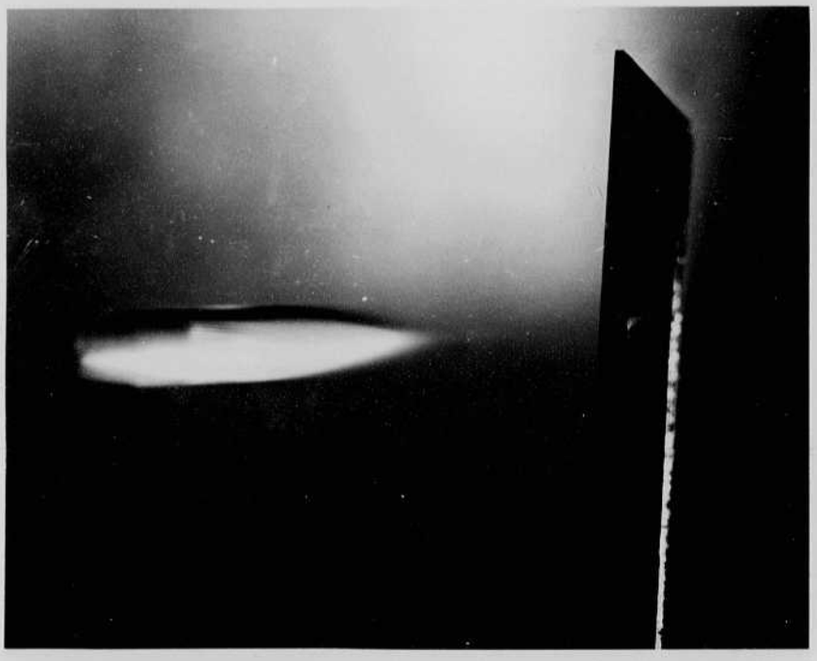
distance 2700 ft/sec = 32400 in/sec.

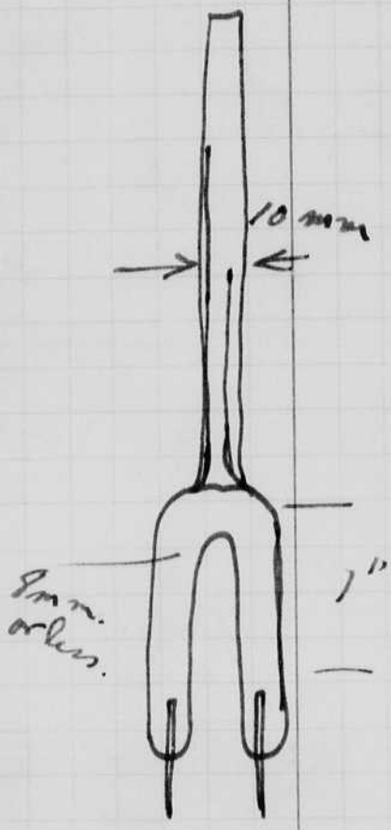
$T = \frac{1/2}{32400} = 2 \times 10^{-5}$ seconds. (1/2 cyc.

$f = \frac{1}{4 \times 10^{-5}} = 25$ c. KC.

The Hg tube is unable to fire. Damping resistance is needed.





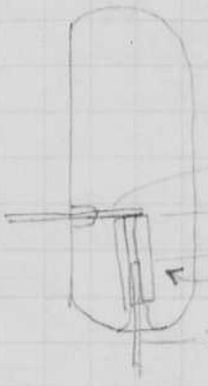

10 mm
1"

July 17 1930

H. E. Edgerton

Further tests upon time of flash of argon lamps at atmospheric temperature.

Tube experimented with.



1800.

17" = 1½" enlargement.
about 10.

1mm camera used 3600 r.p.m. f16 Sonnbrewing film, ½ kf 15,000 volts. A spark gap was put in series with the argon lamp adjusted so that it would go off by itself. A resistance wire was put in series with the argon lamp and gap to ground the oscillations.

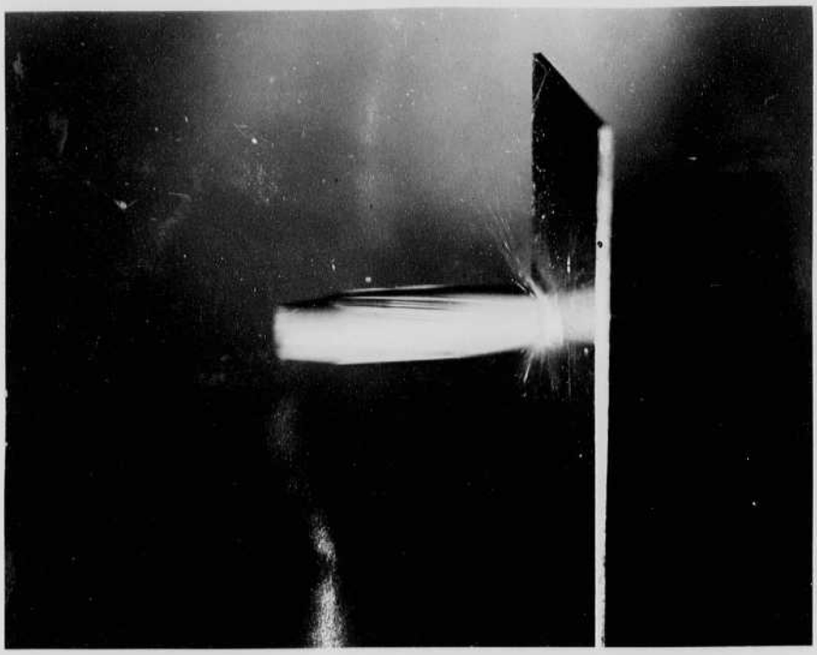
	A	Without slit		
10 ft. sec. 3600 R.P.m.	#1.	2" resistance wire	1.2 ohms / ft. #26. bare.	
"	2	0 " "		
"	3.	14" " "		Slit made smaller.
"	4	26" " "		

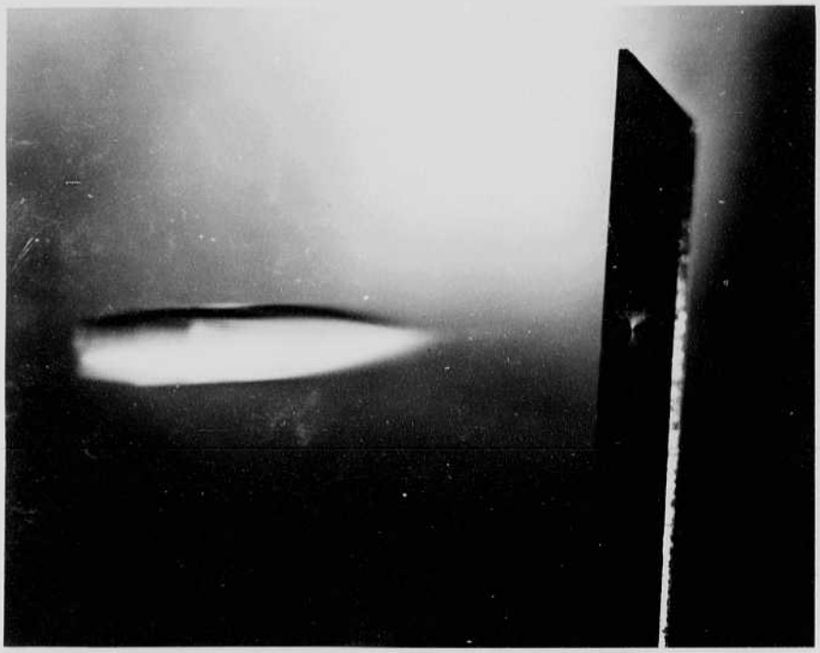
also several on this with 0 resistance for comparison. Film Broke! but was salvaged. Scratched up somewhat

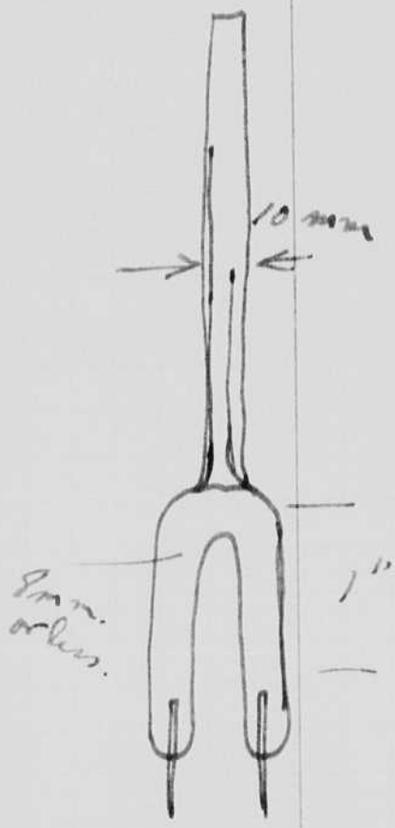
July 18.	5.	0 Res but Hg lamp (Short 3" one)	
	6	0 " Hg lamp Different argon lamp.	No Capillary. 1½" gap. 30cm.

[redacted] ← Enlarged from #4.
← without damping resistor

← with about 2½ ohms.






10 mm
1"
8 mm.
orien.

July 17 1936

G.E. 2 gen. on

Further tests to ascertain time of flash of argon lamps at atmospheric temperature.

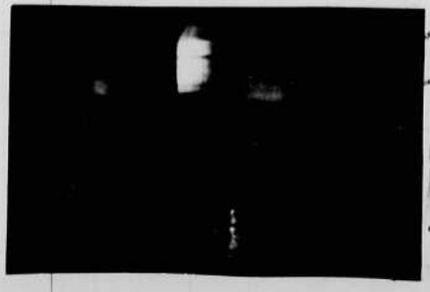
Tube exposed to view.

17" = 1½" enlargement.
about 10.

	A	without slit		
11:45 P.M. 3600 R.P.m.	#1.	2" resistance wire	1.2 ohms / ft. #26. Iron.	
"	2	0 " "		
"	3.	14" " "		Slit made smaller.
"	4	26" " "		

also several on this with 0 resistance for comparison. Film Broke! but was salvaged. Scratched up somewhat

July 18.	5.	0 Res but Hg lamp (Short 3" one)	
	6	0 " Hg lamp Different argon lamp.	No Capilliary. 1½" gap. 30 cm.



← Enlarged from #4.
← without damping resistor

← with about 2½ ohms.

Cont.

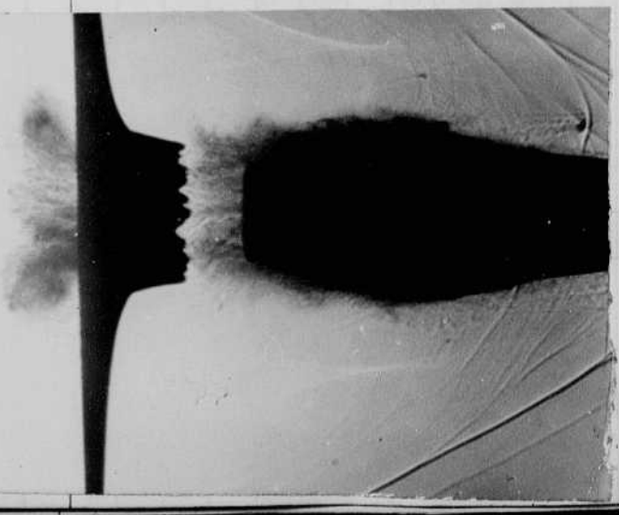
I made a tube as shown on page 36 with about 2" between electrodes. Heated, pumped out, filled with H_2 at 1 cm, ran with glow discharge to both electrodes as cathodes, filled with argon at 1 atmos and sealed off.

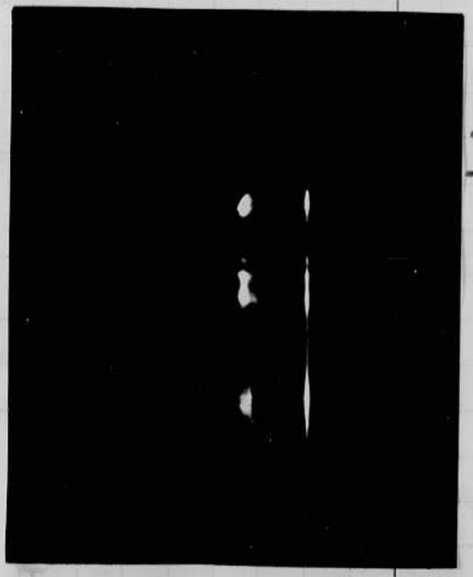
This tube would just about hold off 10,000 volts. In fact it did after firing a few times. A red or yellow deposit flows up the long tube for holding the gap when it fires. After firing the other way to strip it off the tube blew out on the cathode side.

tube repaired and only gave about 3 flashes before it blew and again.

July 20 1936. Cont experiments. Rebuilt argon lamp as described above but with 8 mm O.D. pyrex glass. It broke again but this was due to a strain due to over heating while on exhaust. Repaired and repumped. 1 cm of hydrogen was put in with 1 atmosphere of argon.

7. Argon lamp. 0.5 mf 10,000 v. 3600 RPM.
8. Ditto but with slit (too narrow or not lined up).
9. Argon lamp (1 cm H_2) — Ditto.





July 22 1936.

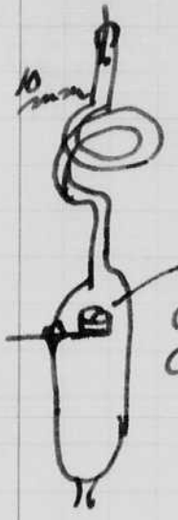
Bez.

took several photos of .30 cal with tube with 1 cm of H2 and 1 atmos of argon. Only one came out and it was timed late. The tube finally blew up.

Another tube was made yesterday of slightly larger tubing and with a slightly longer path. 3 cm of Hg was put in it. This tube holds off the 10,000 or 12000 from the power pack. It trips ok by a spark on the cathode leg.

This morning I talked to Mr Reed of the Watertown Arsenal about the spark photographs. He is writing up a report.

I built a tube for the movie outfit that looks like the following.



An oxide coated cathode was used which Semerhow brought from the Hygrade Co.

It was treated electrically by running an arc discharge through the tube. The CO2 was pumped out.

20 cm of argon was put in the tube and it trips ok. in the 3 kw movie outfit at 700/sec 2 uf. 1200 V ± 400 Volts. Also did run up to 1200 cycles with the same setup. The cathode got red hot and may be too small?

a second tube exactly the same except for cathode was made. It was hard to start when on the pump. Filled with 10 cm argon and tried in the movie outfit, but did not start. Repumped to 4/100 cm and then held over night. Repumped and filled to 5 cm but operation was still

Cont'd

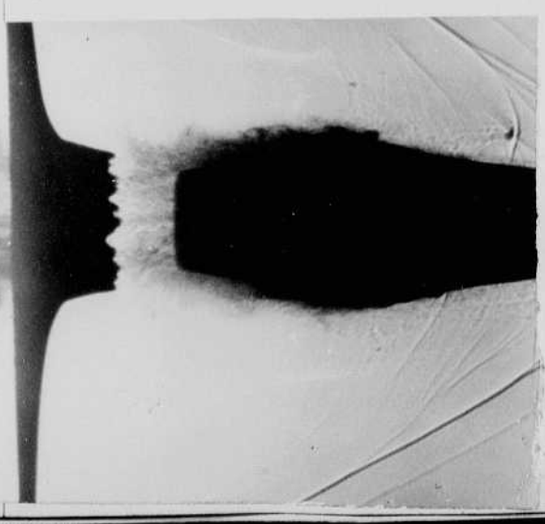
I made a tube as shown on page 36 with about 2" between electrodes. Heated, pumped out, filled with H_2 at 1 cm, ran with glow discharge to both electrodes as cathodes, filled with argon at 1 atmos and sealed off.

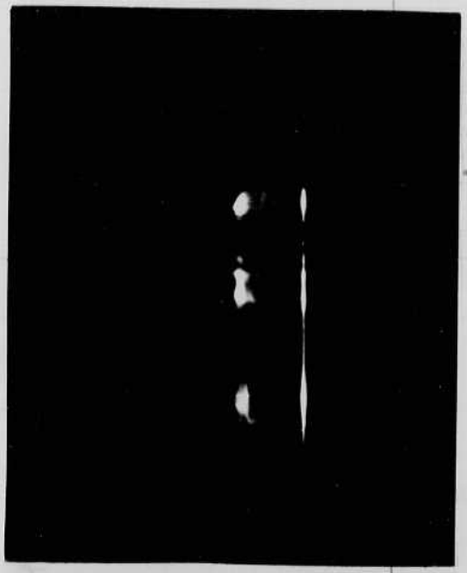
This tube would just about hold off 10,000 volts. In fact it did after firing a few times. A red or yellow deposit grows up the glass tube for holding the gap when it fires. After firing the apparatus to strip it off the tube blew out on the cathode side.

Tube repaired and only gave about 3 flashes before it blew out again.

July 20 1936. Cont experiments. Rebuilt argon lamp as described above but with 8 mm O.D. pyrex glass. It broke again but this was due to a strain due to overheating while an exchange. Repaired and repumped. 1 cm of hydrogen was put in with 1 atmosphere of argon.

7. Argon lamp. 0.5 mf 10,000 v. 3600 RPM.
8. Ditto but with slit (too narrow — not lined up).
9. Argon lamp (1 cm H_2) — Ditto.





Slit

July 22 1936.

Bucc.

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20 cm of argon put in the tube and it trips ok. in the 3 kw movie 700 ma. out fit at 700/sec 2 mf. 1200 V ± also did run up to 1200 cycles with the same setup. The cathode get red hot and may be too small?

a second tube exactly the same except for cathode was made. It was hard to start when on the pump. Filled with 10 cm argon and tried in the movie out fit, but did not start. Repumped to .1 cm. and then held over night. Repumped and filled to 3 cm but operation was still

not very good. I plan to put an oxide cathode in this tube.

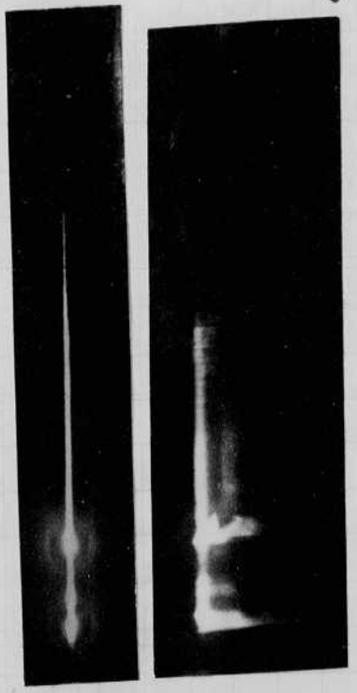
Donald Morse brought a Badington player over and we took one photo which was no. 9. because he hit the bird below the field of the camera. So as to try again next week.

July 25, 1936. Just retured from a two day trip to Hebron N.H. home of Prof. Mat. L. Webster to photograph hovering birds again, both models and stills.

July 28, 1936.

Took time of exposure record upon the tube mentioned on page 37. (top). Results are below. Film Speed (3600 rpm). Enlarged 10 times. @ 200/50 sec approx.

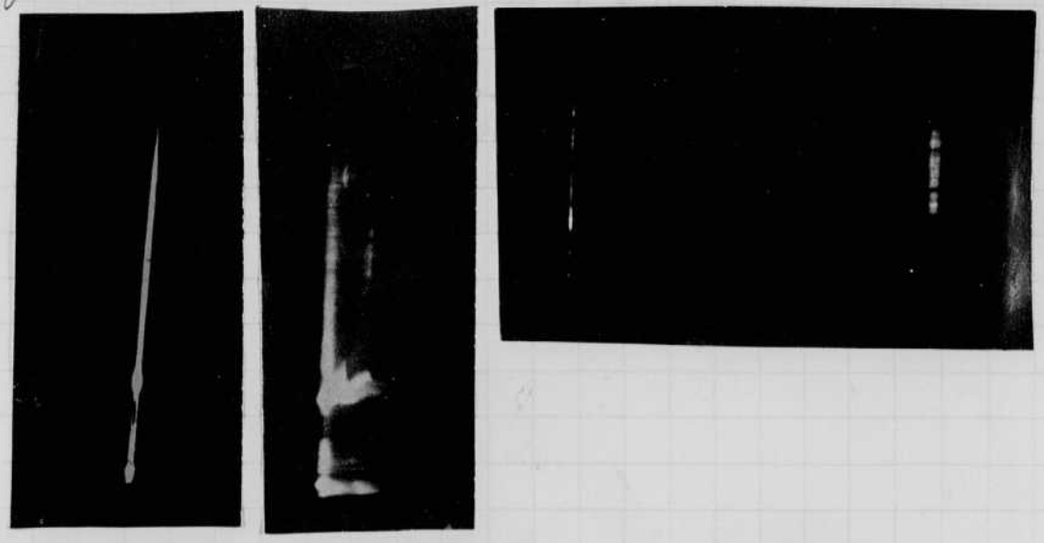
#10



July 30 1934
H. E. Edgerton.

Reduced voltage about 15% and repeated the test shown on opposite page.

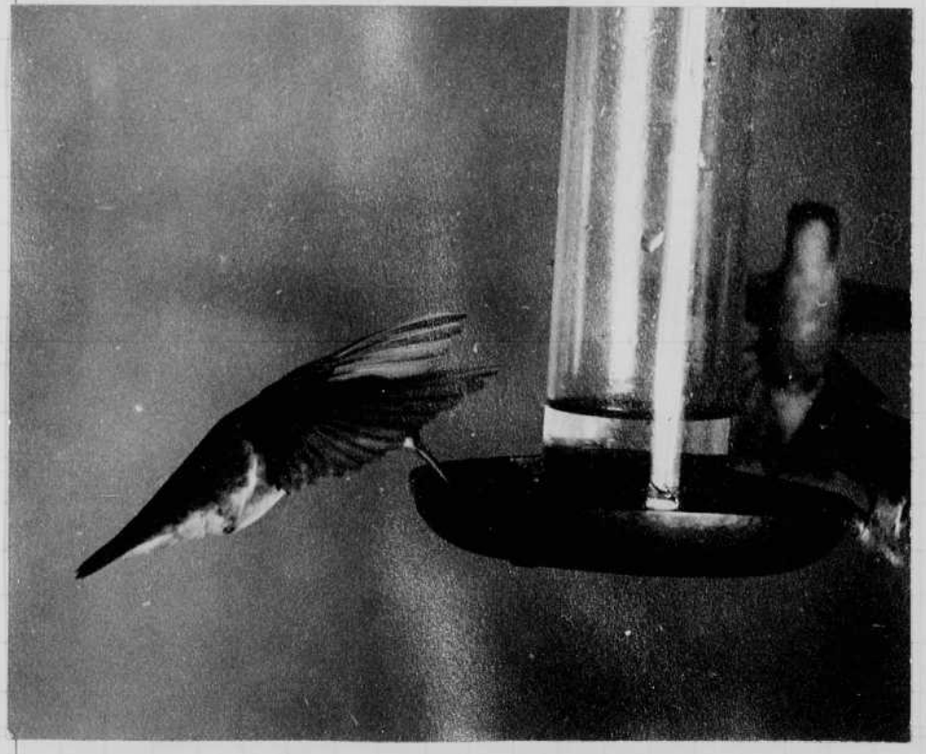
Next tried 1 mf 4000 volts with V shaped quartz tube with 30 cm.



#11

#12

film destroyed



not very good. I plan to put an oxide cathode in this tube.

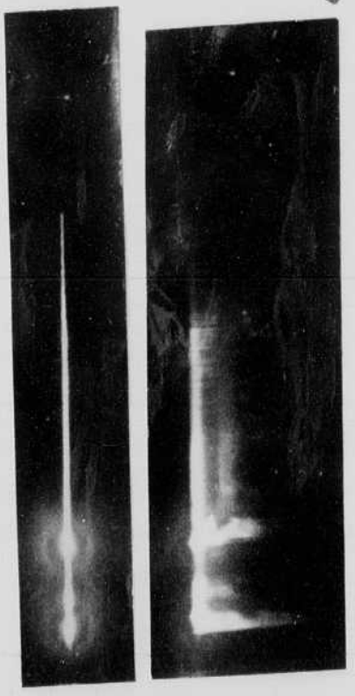
Donald Morse brought a Babington player over and we took one picture which was no. 9. because he hit the bird before the field of the camera. Hope to try again next week.

July 25, 1936. Just returned from a two day trip to Holderness N.H. home of prof. Mat. L. J. Webster to photograph hovering birds again, both models and stills.

July 28, 1936.

Took time of exposure record upon tube mentioned on page 37. (top). Results are below. Film Speed (3600 rpm). Enlarged 10 times. @ 200/10 sec approx.

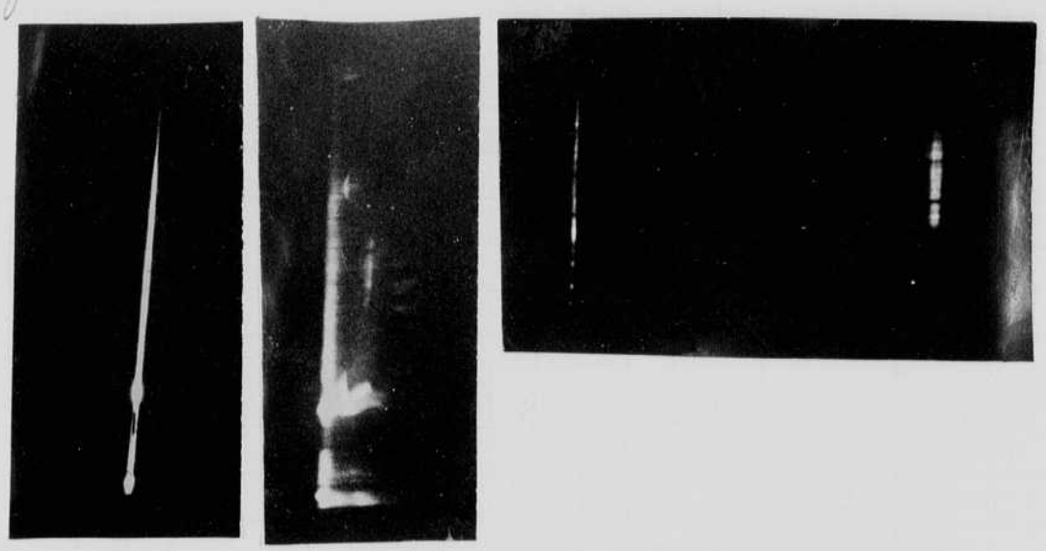
#10



July 30 1934
H. E. Edgerton.

Reduced voltage about 15% and repeated the test shown on opposite page.

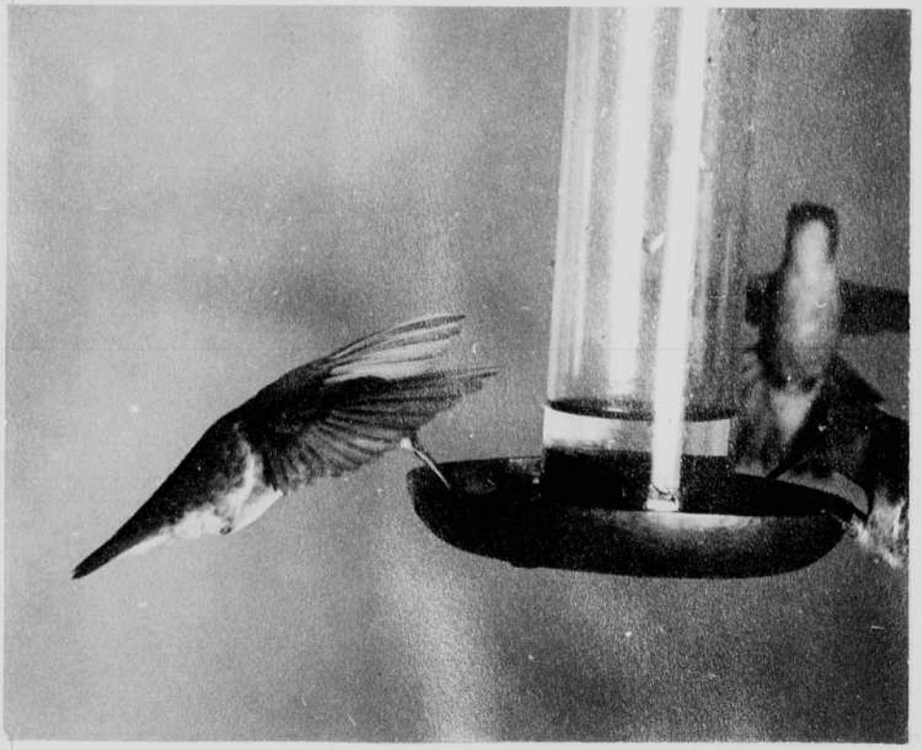
Next tried 1/4 f 4000 volts with V shaped pyrex tube with 30 cm.



#11

#12

film destroyed

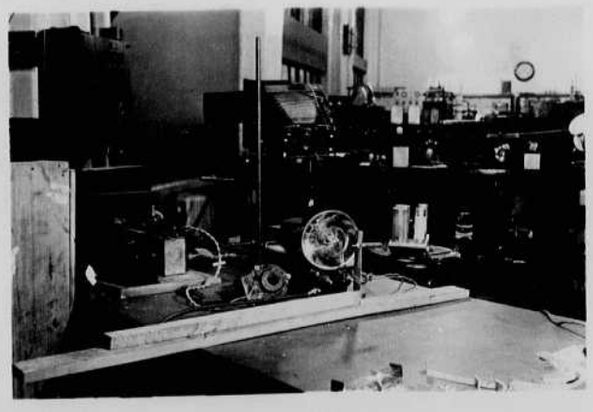


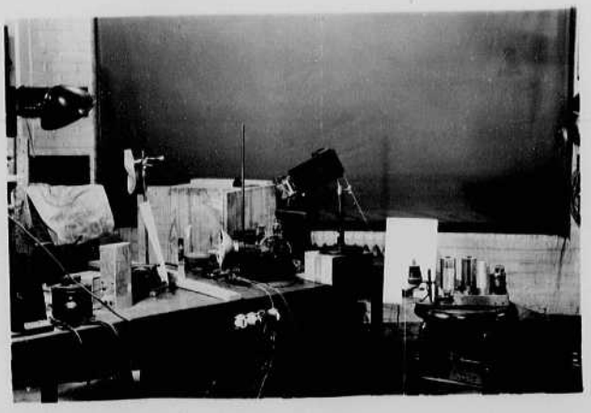
August 1 1936
HE Edgerton.

Worked with Germs last night and today taking bullet photos. The argon tube blew up after three photos. then used 7000 volts .5 mf and U shaped argon Quartz tube. at f 5.6

#13. This morning made another tube of 10 mm pyrex 2" gap. Pumped to 100 microns air and then filled with argon 40 cm. Record 1 flash made. It was used in the afternoon. To take photos with .5 mf and 6000 volts.

f 5.6.
4000 V
0.5 mf
Quartz tube!





Notebook # 7

Filming and Separation Record

4 unmounted photograph(s)

____ negative strip(s)

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

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

Item(s) now housed in accompanying folder.

August 1 1936
HE Edgerton.

Worked with Germs last night and today taking bullet photos. The argon tube blew up after three photos. Then used 7000 volts, .5 mf and U shaped argon Quartz tube. at f 5.6.

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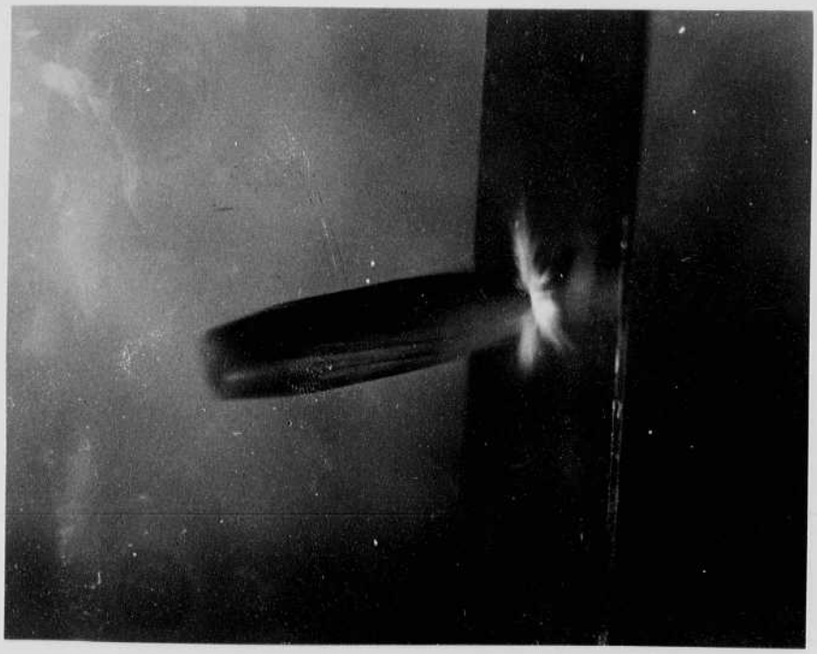
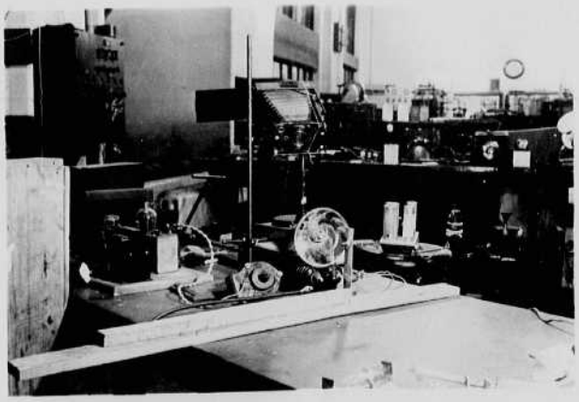
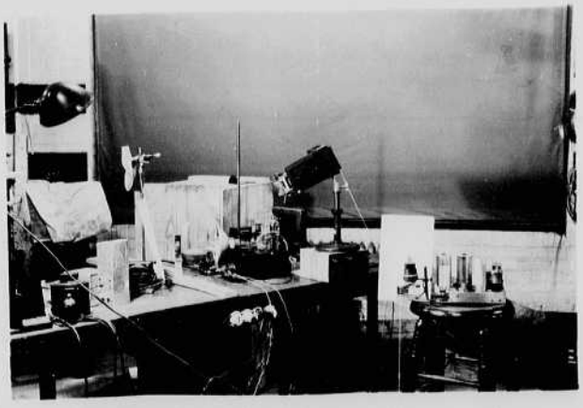
#13.

f 5.6.
4000 v
0.5 mf
Quartz tube.







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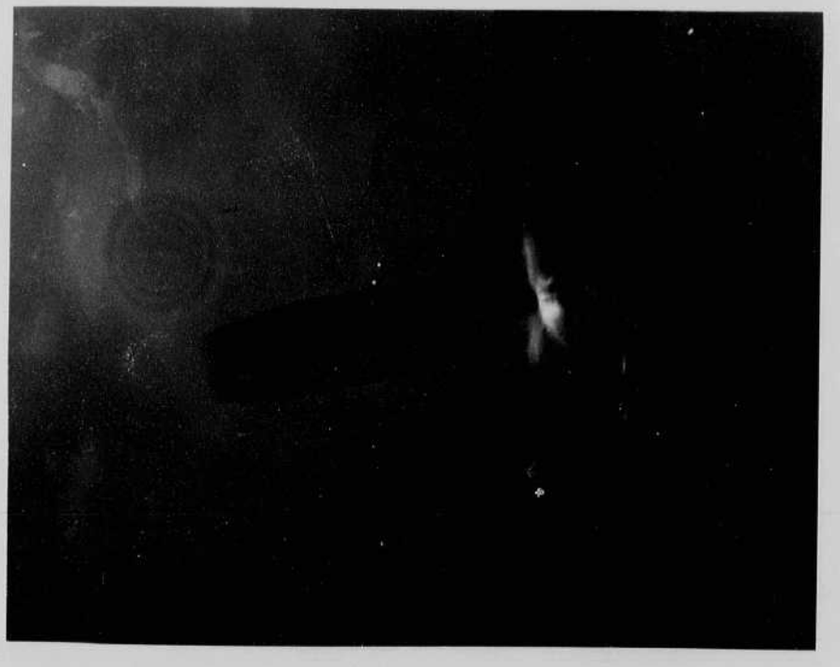
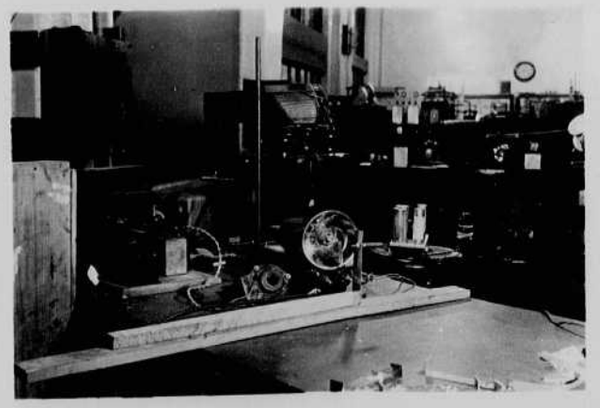
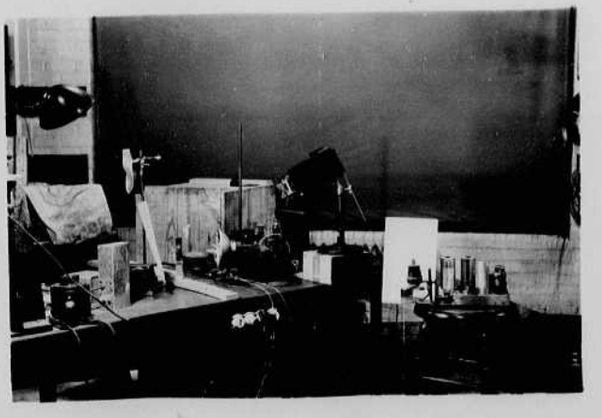


f 5.6.
4000 V
0.5 mf
Quanty tube!





Notebook # 7

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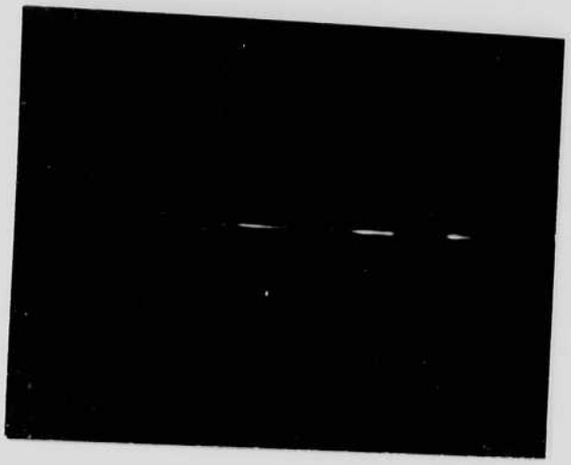
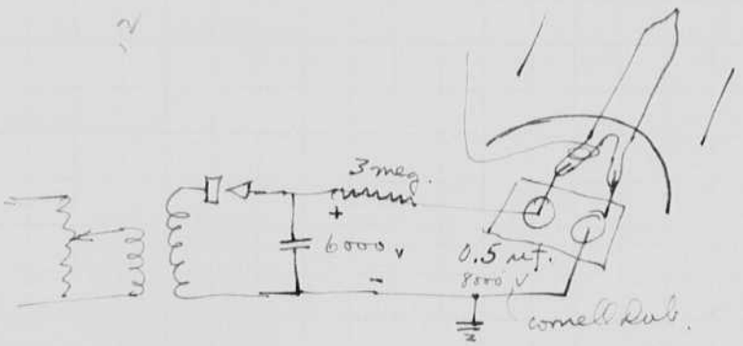
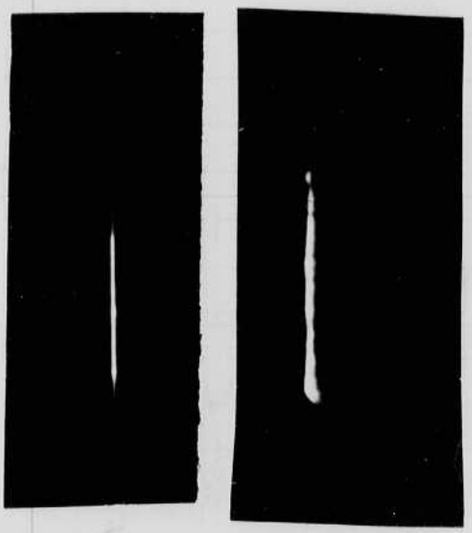
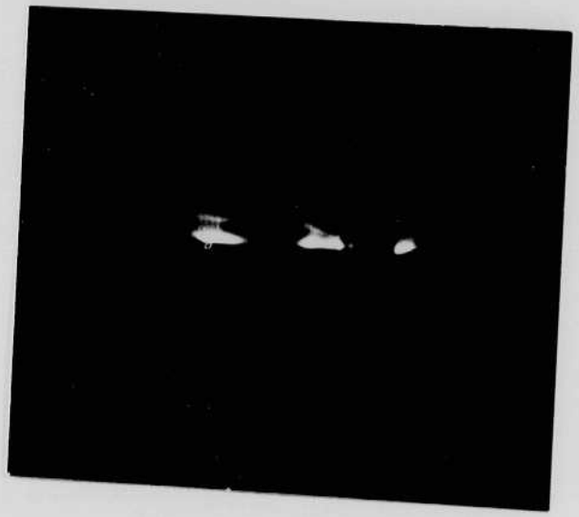


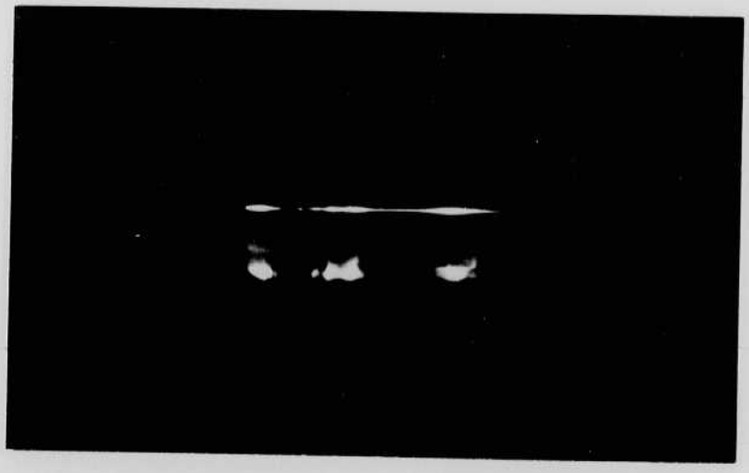
Twelve 9x12 photos were taken with the tube described on the opposite page. All 12 were timed very well. Al sheet, galvanized iron, and rubber were fired at. Lens set at f 11. D76 developer.

Reflector (front to bullet) 6 inches.
Camera to Bullet about 16-18 inches.
Zeiss Ikon camera 9x12 cm. 15 cm lens f 4.5 Tessar
Bullet about 1" [illegible] on film.









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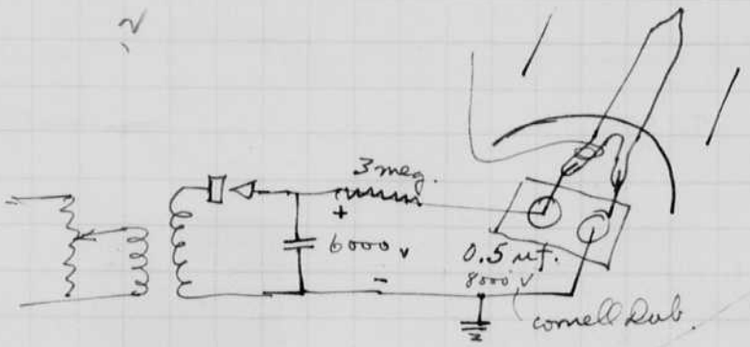
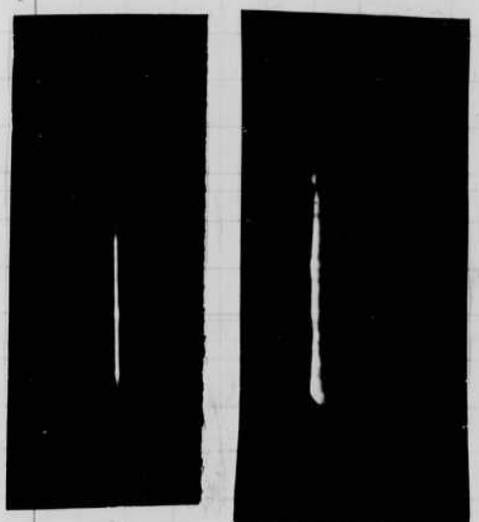
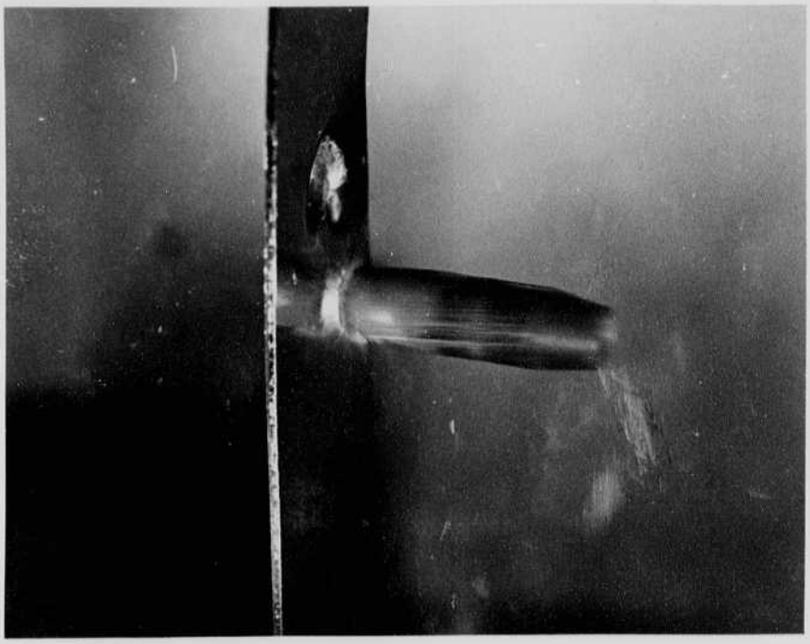
Camera to Bullet about 16-18 inches.
Zeiss Ikon camera 9×12 cm. 15 cm lens f 4.5 Tessar
Bullet about ½ sq. cm. or film.

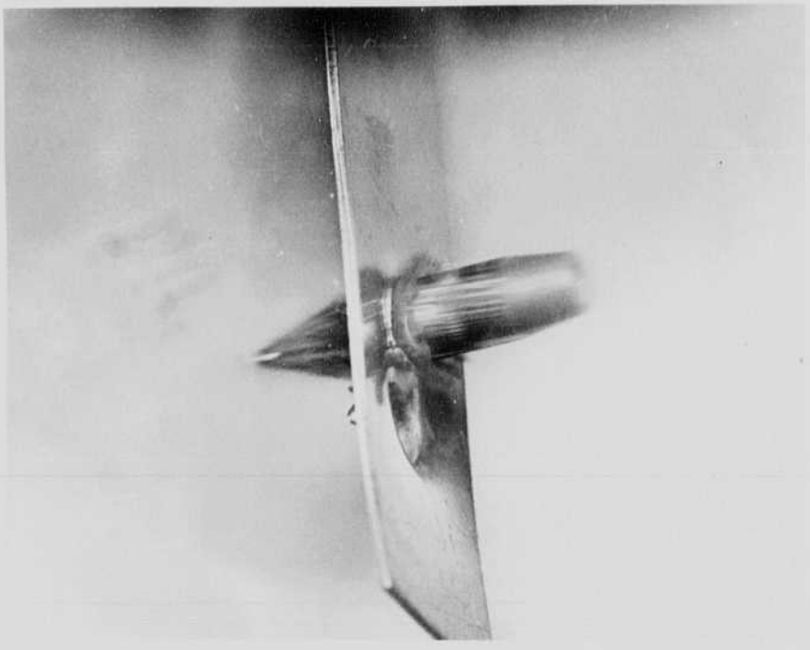


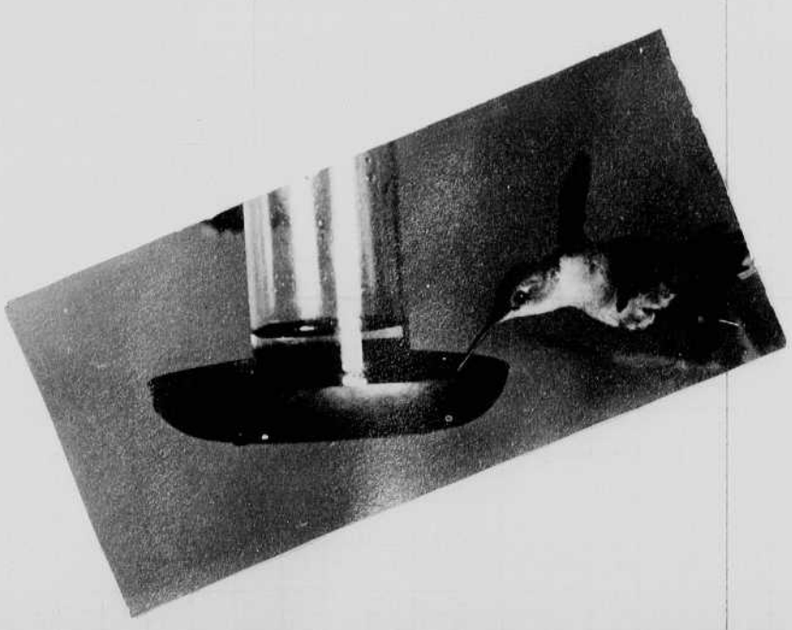


Slit

→ 3000 ft/sec.







Aug 12 1936
DeEdgerton.

On Sat Aug 8 Grier and I took 400 ft of moving at 600/sec of a fish cutting machine at the General Sea Foods corp. on the fish pier. Mr. Brown was developing the machine. Also took 12 snaps with 20 mf 400 volts.

Mac-B. co made me a tube with a 6? mm quartz spiral inside. Also a manifold and pressure manometer for a new all argon system.

← Baked - and sealed with Bombarder. Sealed off with 5 cm. At this pressure the tube will work Ok. as a stroboscope on 1000 volts using an outside spark for excitation.

Tried on movie camera 3 new out fit. 400 ohms 2.25 mf. Worked ok at 600 cycles at first, then started holdover. Works fine at 200 and 150! The pressure should probably be higher.

With 800 ohms, however, and 1.25 mf. it runs ok.

Tube retubulated and repumped to fill to higher pressure. Filled to 10 cm argon. Works ok now 400 ohms 2.25 mf 600 cycles. No holdover. A few misses when started first time.

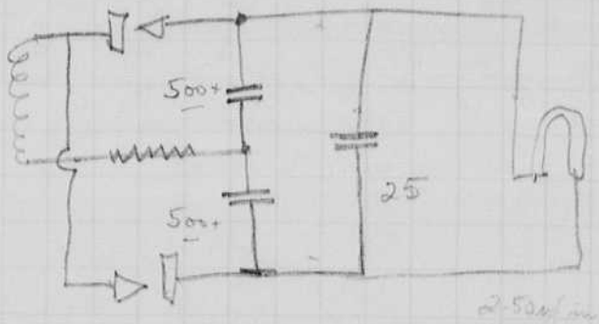
Operation data 4.25 mf. 200 ohms. 850 volts. (1000 volts ac input to work)
600 cycles 2.3 amps. 33.2 amps.
99% at set.

Holdover with (1200 cycles) 2.25 mf 200 ohms.
(3.5 amps dc current).

A film shows ripples

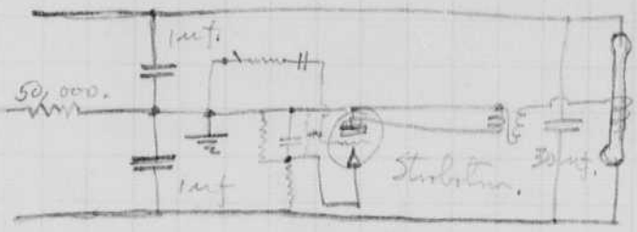
Aug 13 1936

Single-flash outfit.

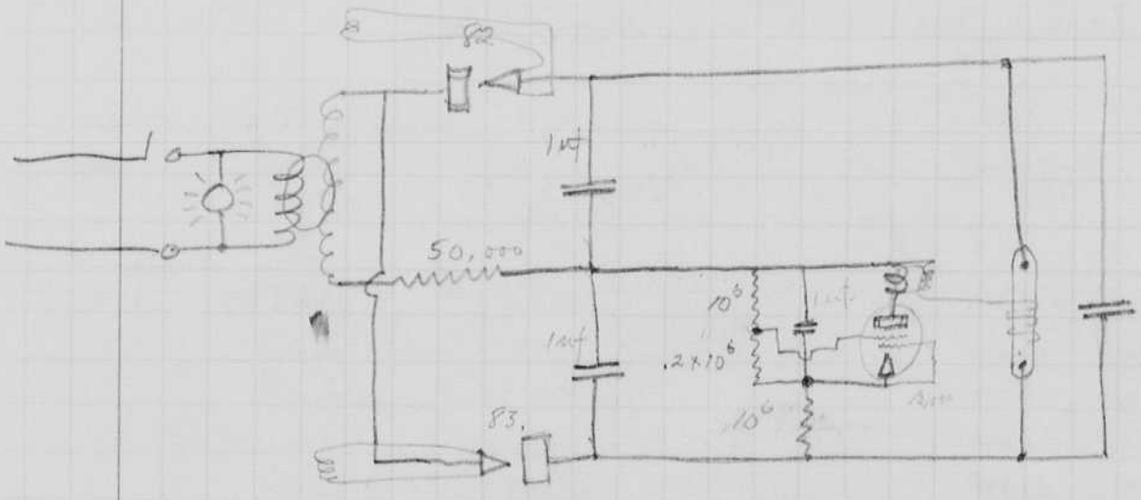


say 25 mf.

2 250 mf in ser. 25 mf. 53.40 600 v dc.
2 20 mf in par 20 mf. 15.60 450 v dc.
2 15 mf in par 30 mf. 25.60. 450 v dc.
Cornell-Dubilier.



Rc = 52cc. C = 30.
$R = \frac{1}{30 \times 10^{-6}} = \frac{10^6}{30} = 100{,}000$ ohms.



cont of p44 Aug. 13, 1936.

Changed over from 3KW single phase power supply to 30 KW 3 phase. Same argon lamps as used yesterday with 10 cm of argon.

Runs ok with 400 ohms charging resistance and 2.25 mf at {600 cycles. 1.5 amps. and {1200 cycles 2.0 amperes. d.c.

The voltage is more than 1000 volts as circuit was off scale with my voltmeter.

(800 and 400 ohms put in parallel). Holds over!

Repumped and filled to 20 cm argon.

Runs ok 200 ohms ~~4.25~~ mf 600 2.85 amps

N.G. at 1200 cycles. with 200 ohms 2.25 mf.

Now folds over.	~~600~~ 1200	cycles	200 "	4.25 mf.	
ok.	600	"	p 400 800 "	4.25	2.45 a.
folds over.	600	"	p 400 800	2.25	
NO	1200	Ditto.			
ok	600		400	2.25	1.45
Pegged	1200		Ditto		2.0 ±

Spark alone sounds bad. Another thyratron put in.

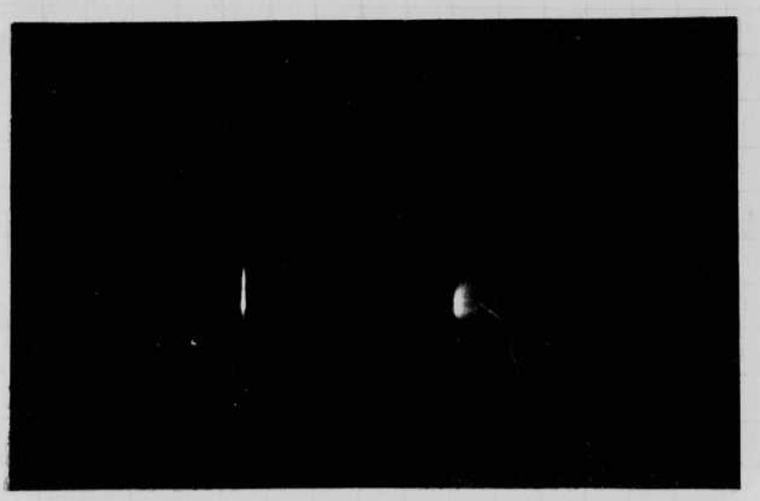
ok.	1200	400	2.25	2.05

Argon tube slightly grassy
Repumped again to 20 cm.

ok.	600	400	2.25 mf.	
jumps	1200	400	2.25	
folds over	1200	par 400 800	2.25	
"	1200	400	1.25	
skips	600	800	2.25	
skips	600	800	1.25	
"	1200	800	1.25	
now O/K!	600	800	1.25	
NO. ok ok ok.	600	400	2.25	1.5
ok ok	600	400	4.25	1.9
ok ok	600	par 400 800	4.25	2.4

Aug 17 1936

test of 0.2 mf 25000 volt condenser
Cornell Dublier type MC 226 No 361492.
1/4" air gap. short leads.



Aug 19 1936
Pumped tube 4 mm. I.D. Quartz (like p 44). ←
20 cm Argon.

took series of water drops falling into water. Regular illumination.

1. 1" drop height. 600/sec.
2. 3 ± "
3 6 1/2"
4 14 "
5 20 "

2 mf 400 ohms 1700 volts ±.
f 3.5 Reg. negative.

6 7' 10" 1/4 500 250 + 200 Ω
7 14 ft ± 1/2 500 300 Ω
8 Same
9 " Some soap in H2O
10 " First drop. 1 1/4

Movies of clear Lyon jumping 250 pict/sec ±. 5.5 mf. Argon 1200 V neg

S.E. Circuit Breaker 600/sec 2 mf 400 ohms. (31 new pd.) f2 Found Rev. Jdg.
Cup breaking 400/sec ± 4 mf (400+200 in par.) " neg. f2
Jug of water 400/sec ± 4 mf 200 ohm (30 mm) negative. f2

Cont'd from p48 Aug 3, 1936.

Aug 17 1936

test of 0.2 mf 25000 volt condenser
Cornell Dublier type MC 226 No 361492.
1/4" air gap. about 4 leads.

Aug 19 1936
Pumped tube 4 mm. I.D. Quartz (like p 44). ←
20 cm Argon.

took serie of water drops falling into water. Rear illumination.

1. 1" drop height. 600/sec.
2. 3 ± "
3 6 1/2 "
4 14 "
5 20 "

Aug. 24 1936

Aug 25 36.

2 — Milkweed Ref. Light 100/sec f 4.5 2 mf 440 ohms. S.R. Pos. 2 inch drop.
Closeup. " " 63 2 " " "
Closeup 2 " " 4.5 2.25 " " "

" " " Bubble.
Dropping
etc.

Sept 5 1936. Worked on Bridgewheel (Newton).
6 " " on oft
7 Sailing in Harbor with Caldwell and Mike Sexton.
8. Fixing up for Arsenal job of photographing
.30 cal bullets.

10 Wagon. Hiking and Exploring from the Indian
Lookout to Lower Chestnut Hill Reservoir.

[redacted]

0.2 mf (25000 V) condensers.
Frog argon lamps 1 atsm
1200 volts.

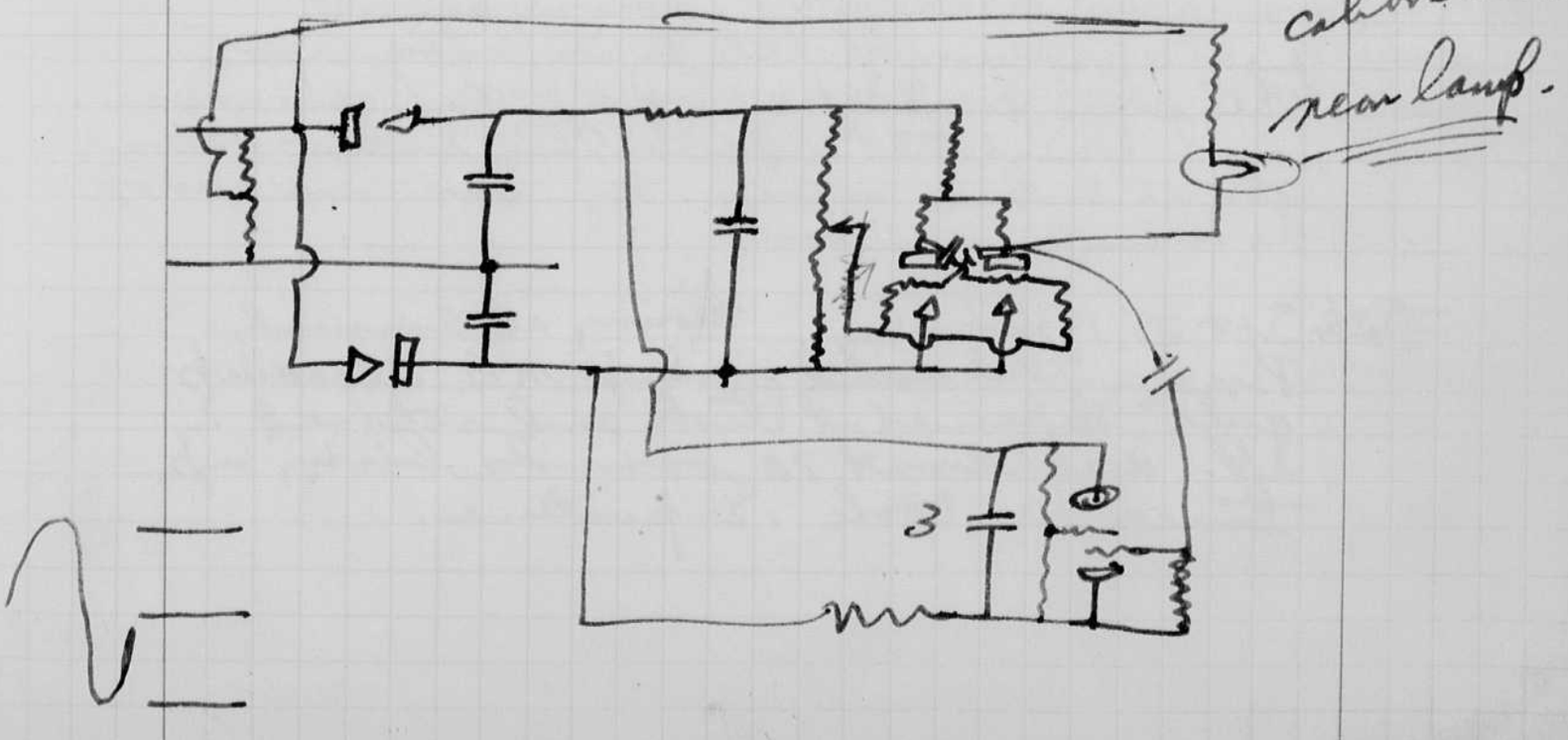
Grier and I took out the condenser, lights, crystal amplifier, etc to the Watertown Arsenal. The pit was full of water.

Sept 11. Stopped this morning at the arsenal, arranged to dry out pit for photographic work.
Received 6 tubes for S.R. Strobe from MacBeth Co. to be pumped and filled with argon.

Sept 17. 36. trip to Newton company to deliver film.
Movies of Cygnus Bridalveil I.T.E.
2.25 mf 550 ohms 400-600 f20 Sound Pos.
One record 90 amps. 220 volts.

Simplified Stroboscope.

1. Single range scale 600 - 3600.
2. 0-100 dial.
3. no trimmers for speed calib.
4. tubes 1 - 2525 Rectifier.
   2 - 6C5 triodes
   1 - ~~6B~~1-P Strobotron.
5. Heater cord. 300 ma 115 - (25 + 12.6).
6. Contactor
7. 60 cycle tie in.
8. No reed.



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Frog argon lamp 1 atsm
1200 volts.

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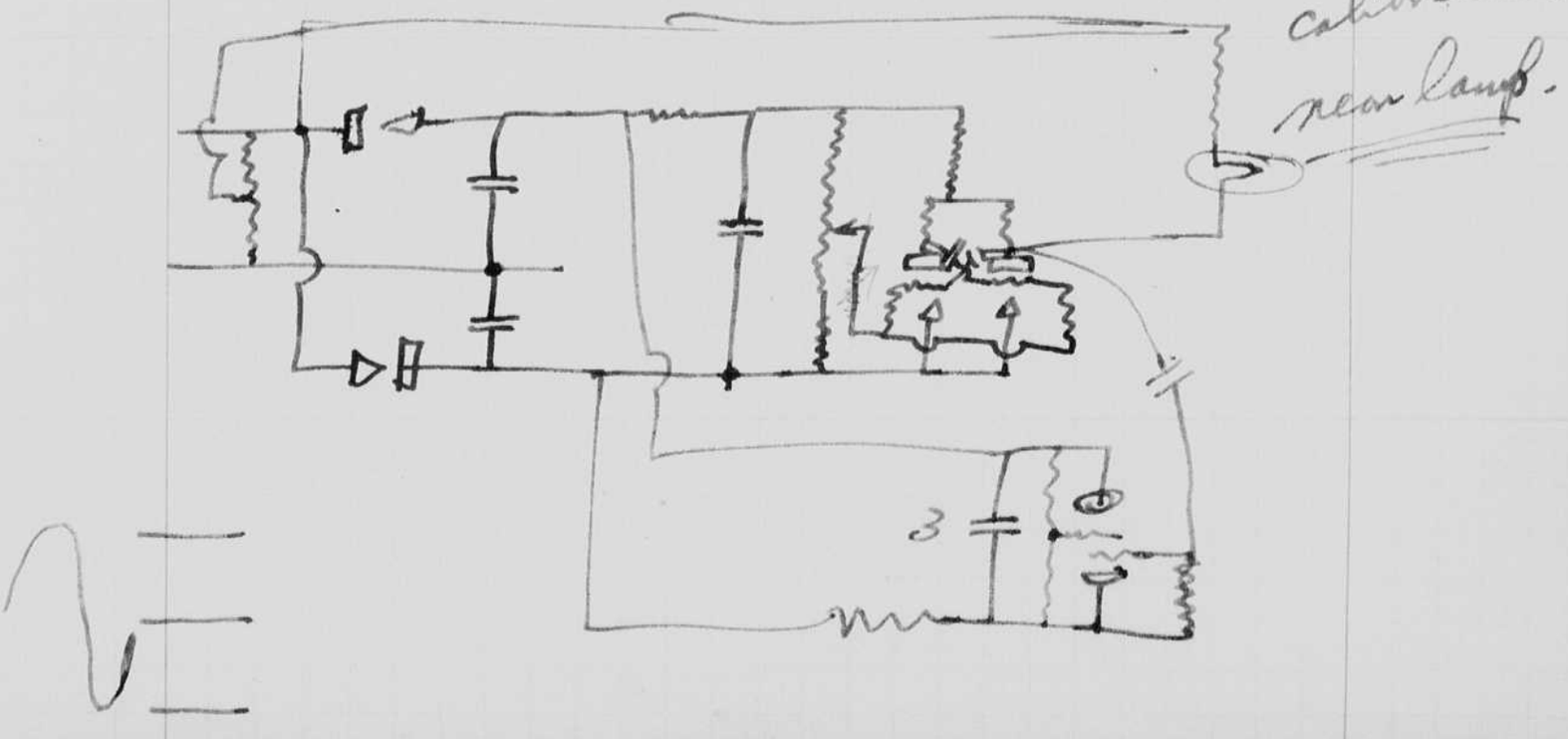
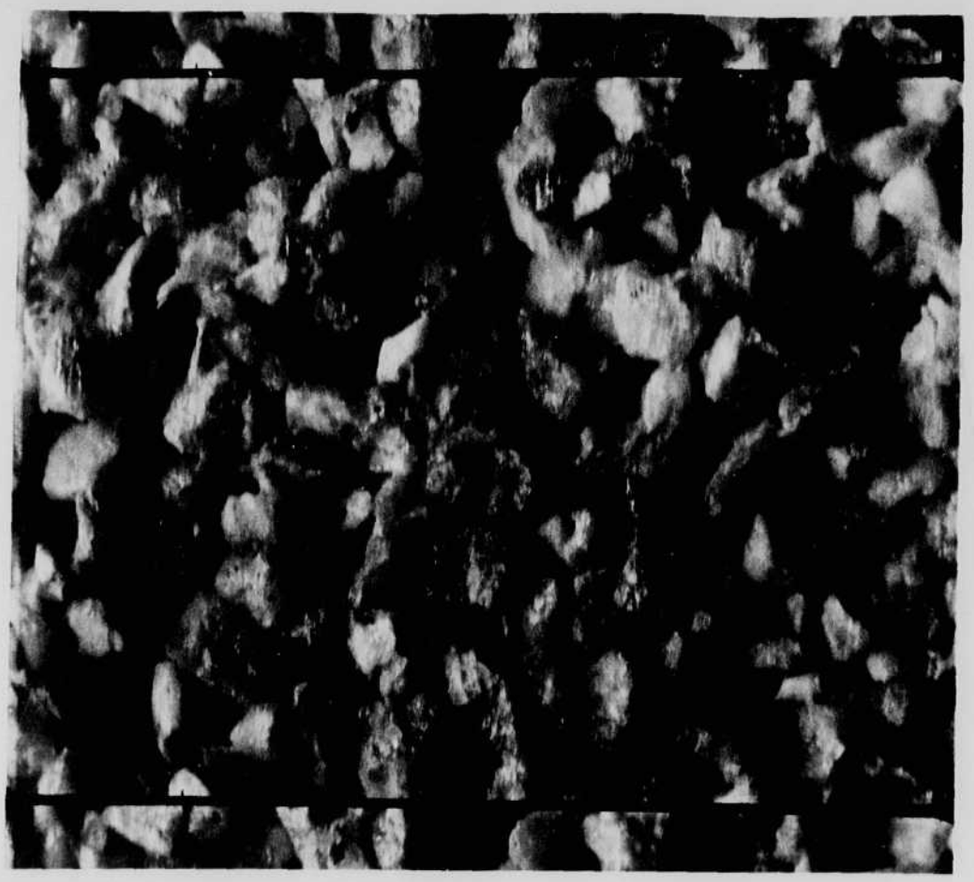
Sept 11. Stopped this morning at the arsenal, arranged to stay out for photographic work.
Received 6 tubes for S.R. Stroboscope from MacBeth Co. to be pumped and filled with argon.

Sept 17. 36. trip to motor company to deliver film.
Movies of Cyrano Bridalzer I.T.E.
2.25 mf 550 ohms 400-600 for 20 Sound Pics.
One record 90 amps. 220 volts.

Simplified Stroboscope.

1. Single range scale 600 - 3600.
2. 0-100 dial.
3. no trimmers for speed calib.
4. tubes 1 - 2525 Rectifier.
   2 - 6C5 triodes
   1 - 884-P Strobotron.
5. Heater cord. 300 ma 115 - (25 + 12.6).
6. Contactor
7. 60 cycle tie in.
8. No reed.





Enlarged grinding wheel frame. Norton Co job
See set up photo page 52.

Sept 23 1936.

Yesterday Drier & I went to the Watertown arsenal and set up the apparatus for photographing bullets by reflected light. The piezo amplifier was out of commission so we brought it back to Tech and repaired several broken wires. Major Dion(?) new head of the laboratory was there.

~~Sat.~~ Sept 25, 1936 Friday morning at arsenal. Piezo crystal sound pickup M.G. also camp gun. Repaired at Tech and returned in afternoon. Used about 70 rounds firing up times then took 12 pictures.

H E Edgerton.

Sept 26 1936

movie of arc dropping on flow.
+2. Neg. Par opened 3.25 at 400 lms. 30 KW 600/sec.

Sept 27. Repumped argon lamp 4 mm see page 47. Sealed off with 20 cm argon on new system. Baked 3 hours +. Bombarded electrodes.

The transformerless strobotac described in Note Book 6 was given to Wilkins of General Radio Co several weeks ago for experimentation. It has 2 25-Z6 rectifiers and 2 6C5 triodes.

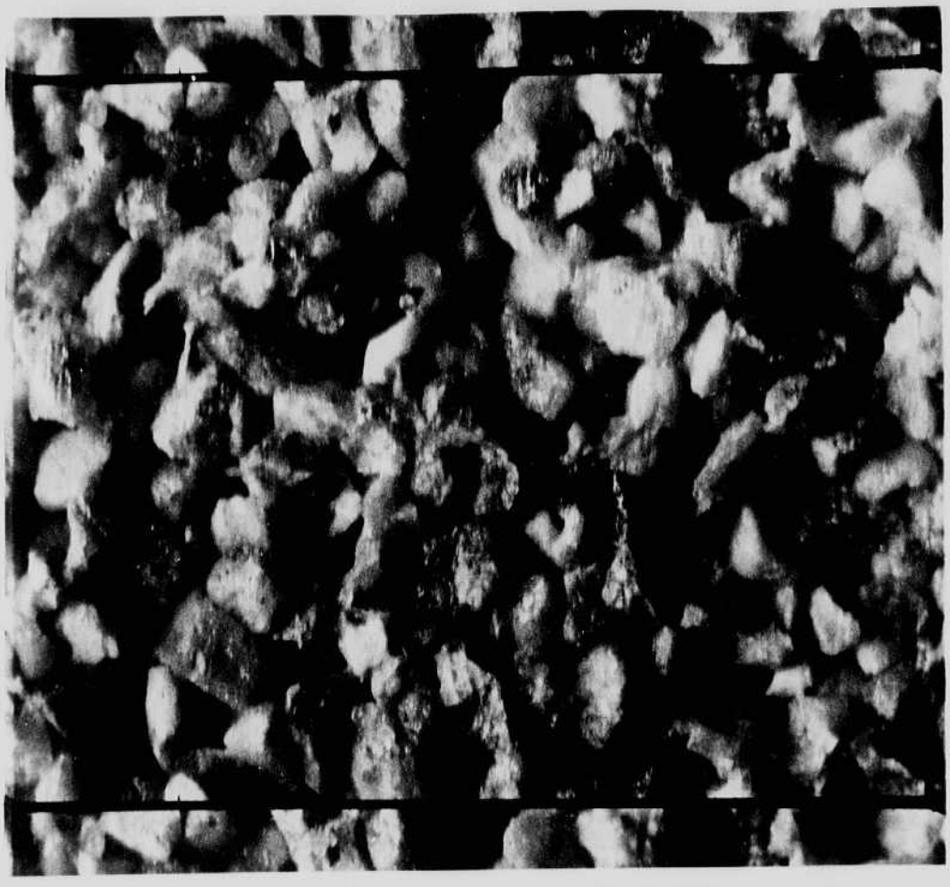
Grier is building up a single range model after scheme on p 49. of this N.B.

Oct. 5, 1936.

Last week (Oct 2?) I took the instantaneous photos of the .30 cal AP against armor plate out to the arsenal. Showed to Col. Jenks and others, about 10 or 15 student officers were out there and were shown the setup.

Dr Reed is going to polish the back side of an armor plate and scribe it with lines so that we can photograph it from the rear.

School started Sept 29.



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H.E. Edgerton.
Sept 26 1936

Movie of arc dropping in flow.
#2. Neg. Par oped 3.25 uf 400 ohms. 30 KW 600/sec.

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School started Sept 29.

Norton Co.

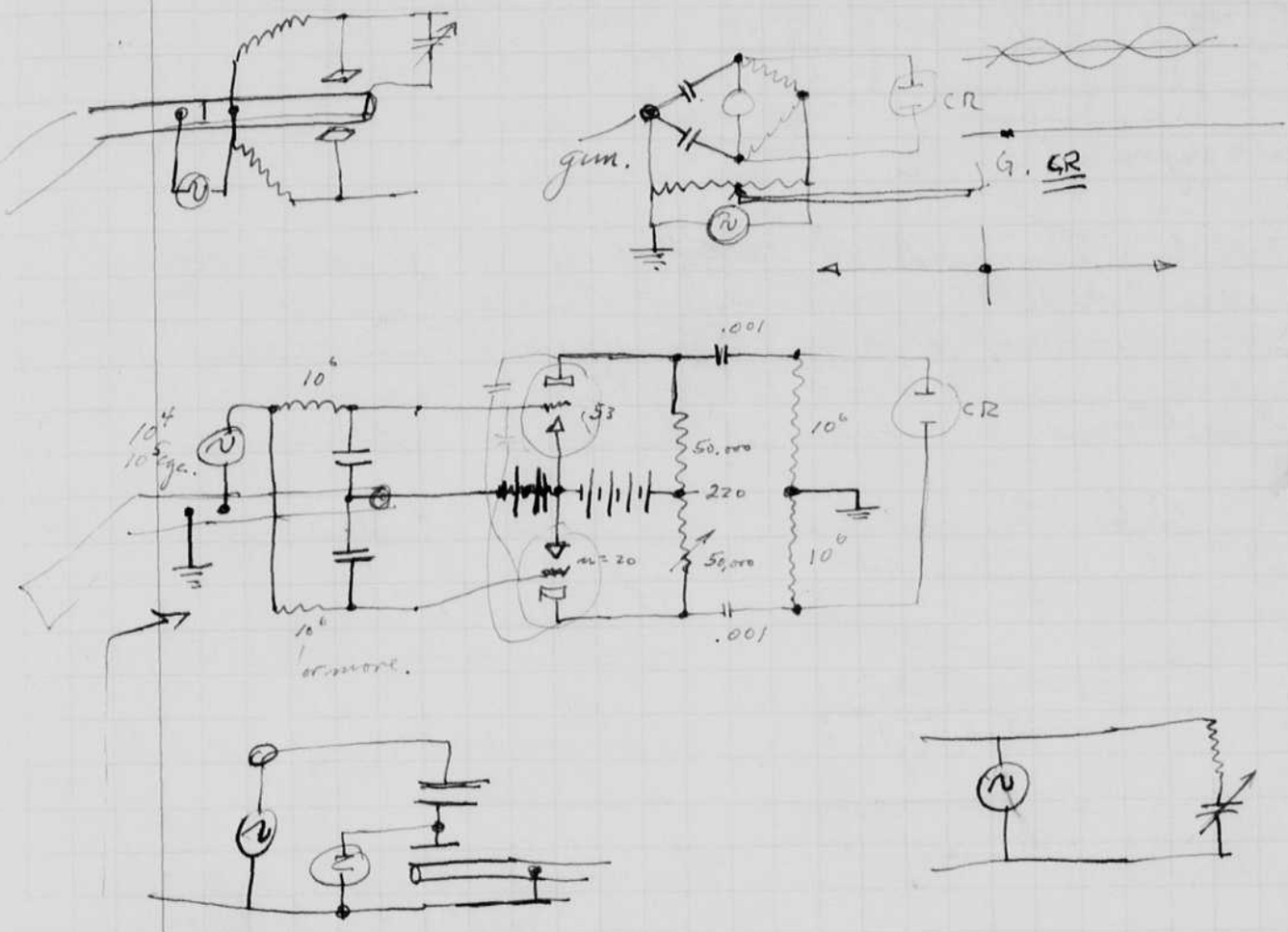
Whitcomb

Wagner.

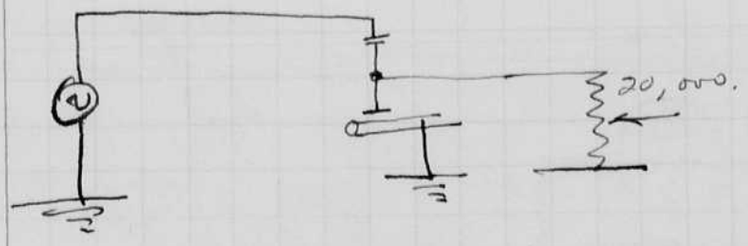
Englund

Capacity displacement bridge.

Oct. 6, 1936 for measuring rifle vibration.



Amplifier changed to read output.



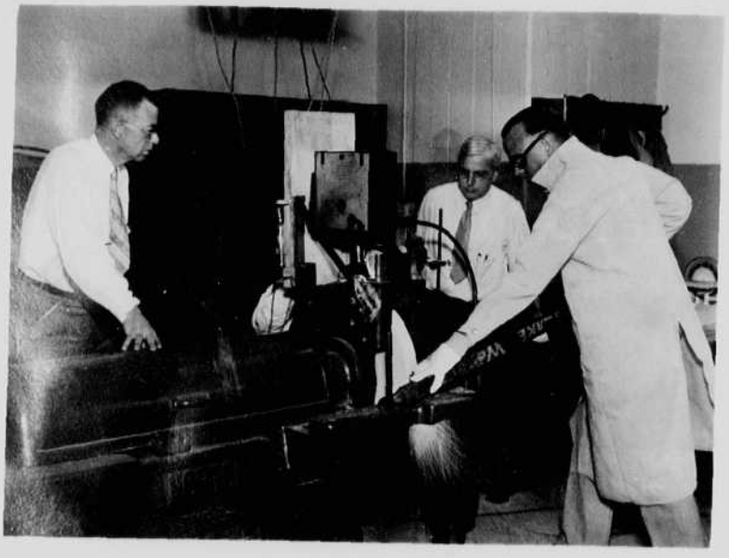
A regenerative amplifier was tried in the circuit shown above. The scheme worked fairly well when the R.F. oscillator was turned off & the regeneration turned up until oscillations were just starting.

Norton Co.

Whitcomb

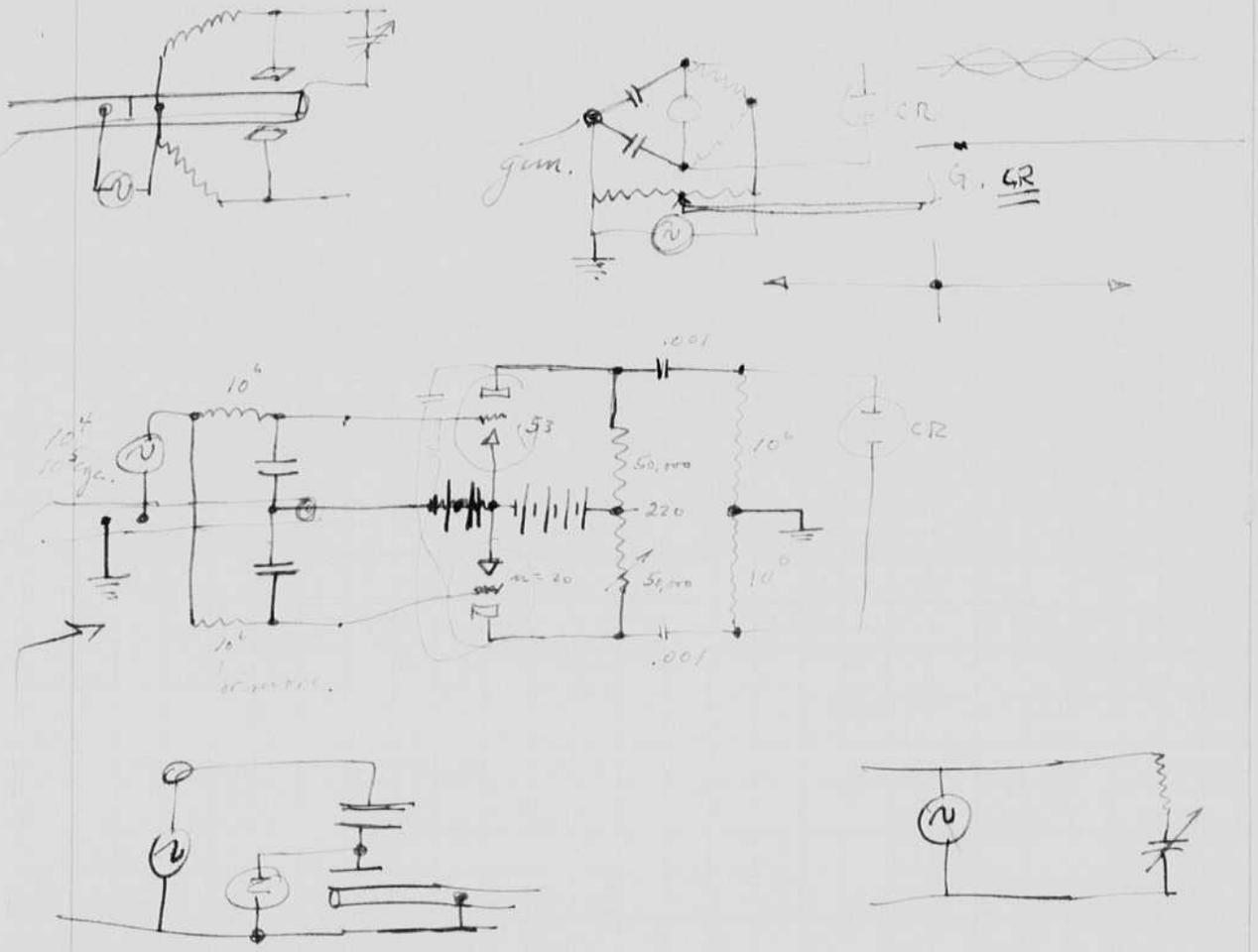
Wagner.

England

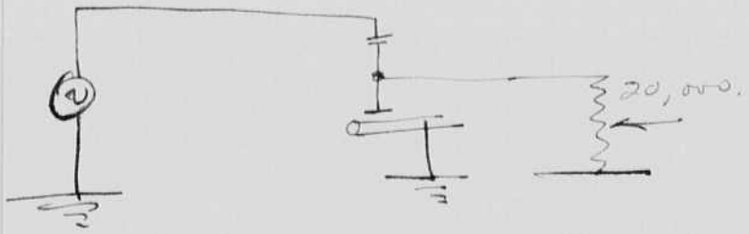


Oct. 6, 1936

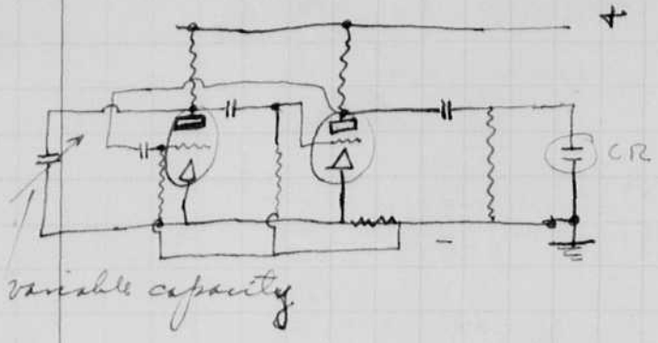
Capacity displacement bridge.
for measuring rifle vibration.



Amplifier changed to read output.

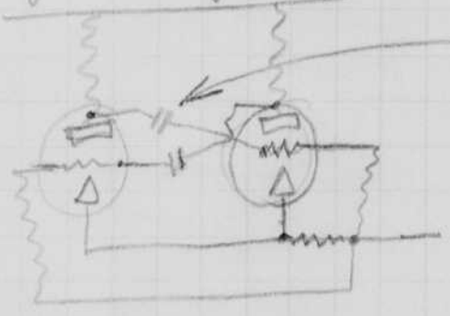


A regenerative amplifier was tried in this circuit shown above. The scheme worked fairly well when the R.F. oscillator was turned off entirely the regeneration turned up until oscillations were just starting.



Oct. 7, 1936. Thomas Wood called from N.Y. this morning about a letter written yesterday concerning movies and stills of Joe Lewis. Gernsback and Brier are to leave tonight for N.Y. and meet him tomorrow noon at the Chrysler building.

Capacity feed back for meas. of displacement

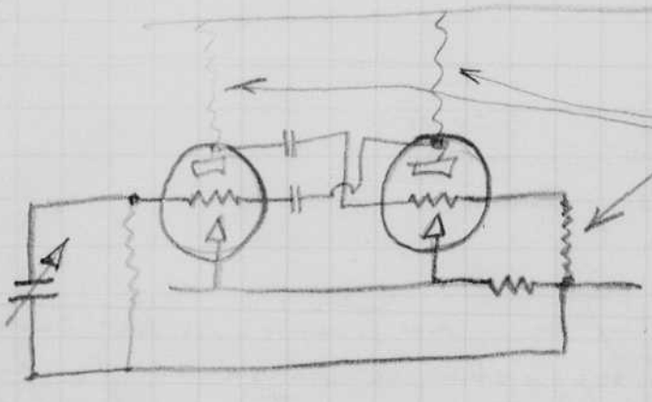


Let this be the variable capacity.

Neither end is grounded! a disadvantage.

The plate-ground capacity change might be better as per above diagram.

Possibly grid to ground would be more effective



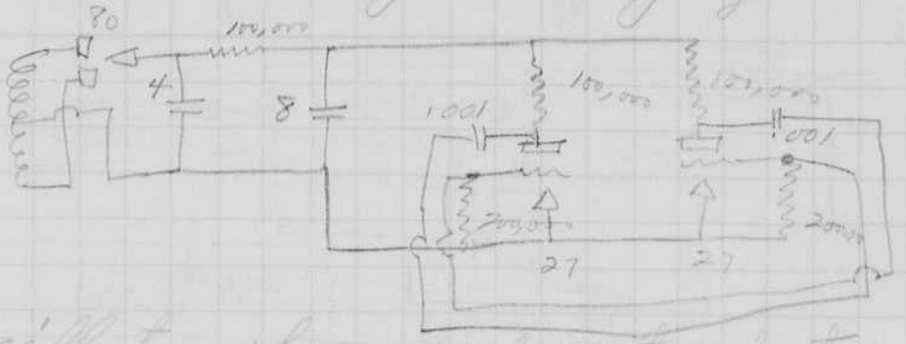
Also use tuned circuit in other grid. or plate

try 27 type tubes.

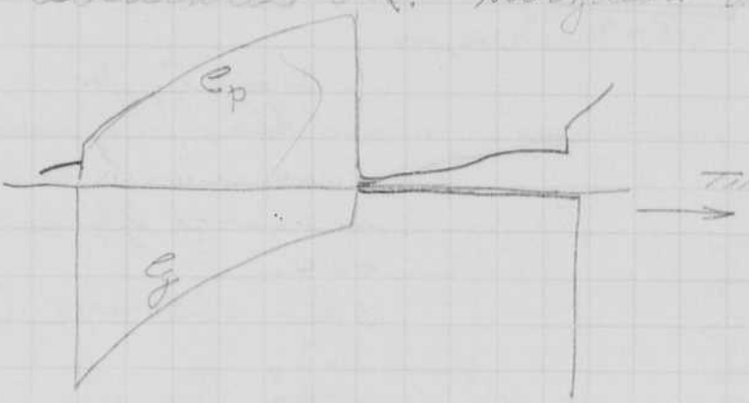
Make plate resistors large and grid resistors small.

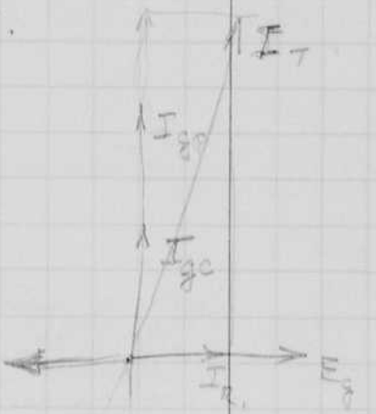
Oct 8 1936
H E Edgerton

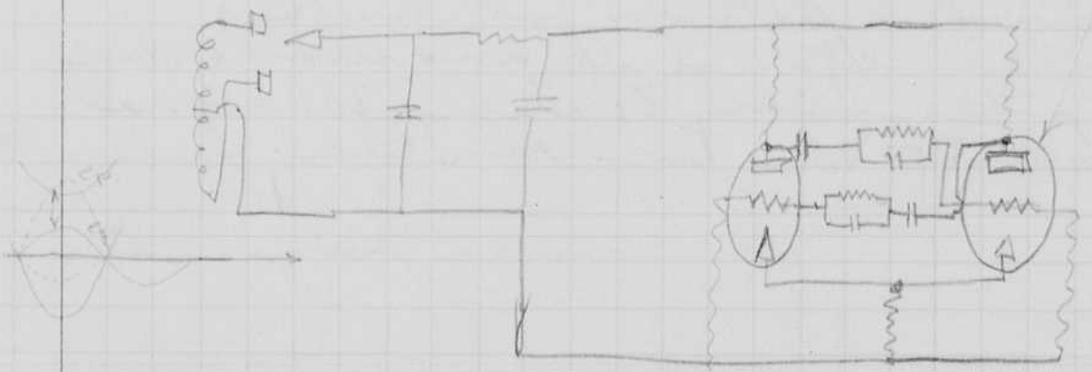
Evening. Wiring up relax oscillator as discussed on previous page.

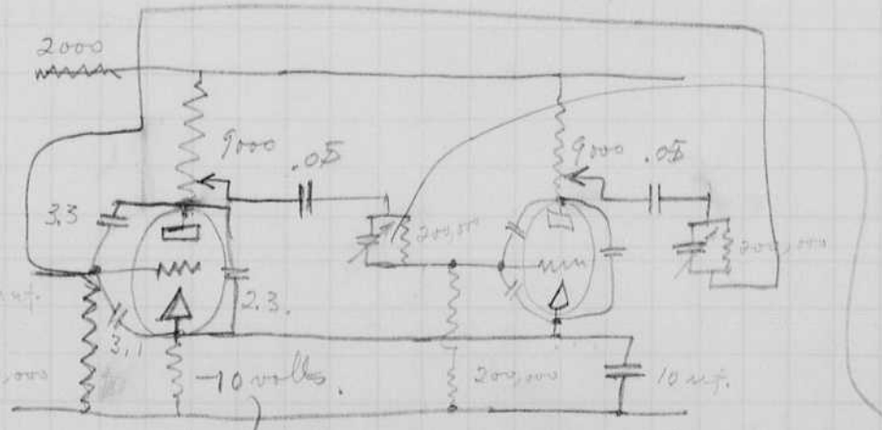


Oscillates abt. 1000 cycles or thereabouts.









27
$\mu = 9$
$r_p = 9100$

6x2 = 12 ma 1000 ohms.

50,000 cycles.

350
900
1150

2,000
.06
120.00

3.3
4.5
165
142
1585

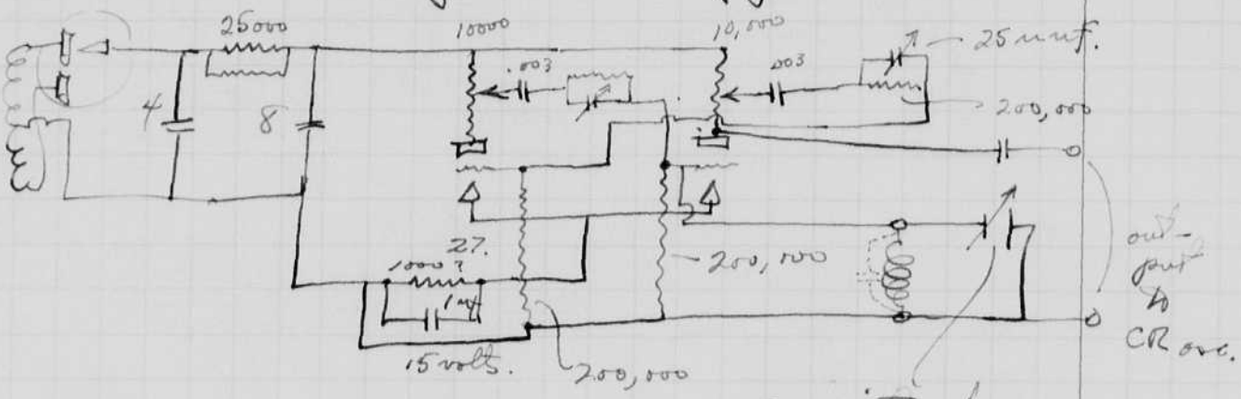
3.1
15.8
18.9

18.9 - 3.1 = 15.8 mmf.

H22.

Oct 10 1936

Spent afternoon working with circuit bottom page 55.
It shows some very interesting possibilities!

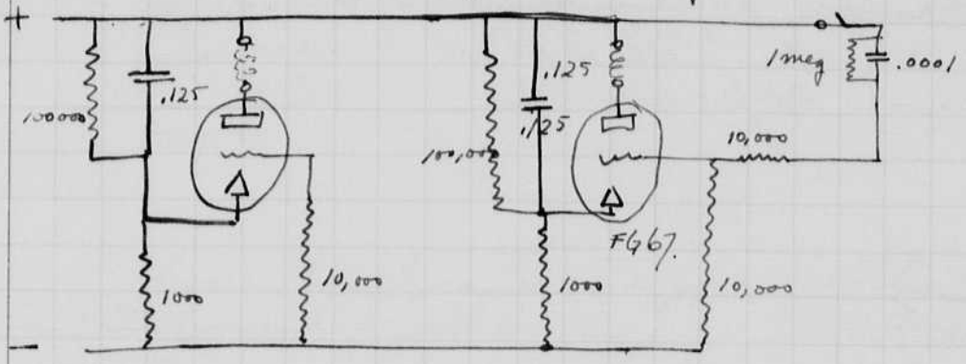


capacity for
meas displacement.
5 division on condenser
means 3/4 inch of arc.
5 div. = 20 mmf ?

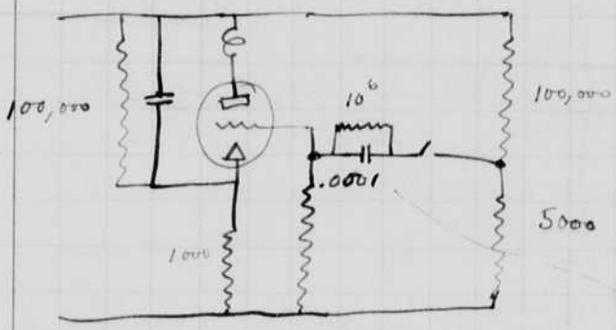
The output was increased by using an amplifier after the above was determined. A plate was put close to a rifle barrel and it was moved back and forth slightly to change the signal
Bullock and Came over here today and saw it.

Oct 11 1936
~~Edgerton~~

Revived double thyratron set and tested.
Circuit now is following.



Tried to reduce the voltage across the commutation



The thyratron does not start with this combination.

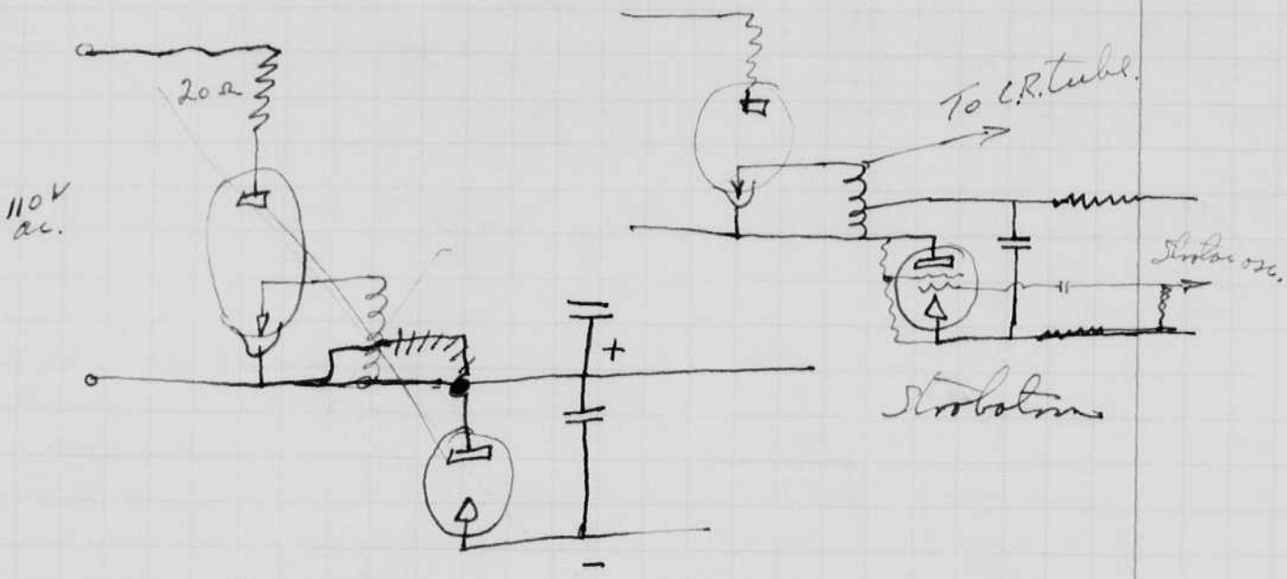
Capacity increased to .01 mf but the thyratron still did not start.

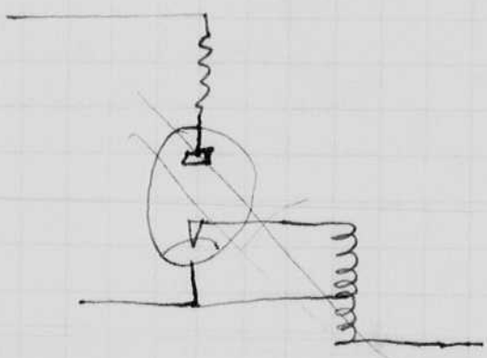
Changed back to above

Oct 12 1936

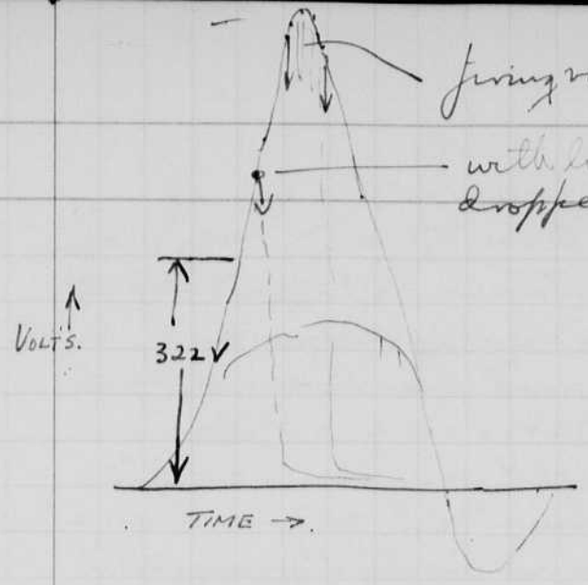
H. H. Edgerton. Cathode ray meas. of Ignitron starting characteristics

Gennesharsen experimented this a.m. on Ignitron setup. He left at 3 and I continued experiments.





The plate voltage of one of the strobotac oscillator plates was used as a sweep voltage. Used on the most sensitive plates of the C.R. tube FP 54 5000 volts plate voltage. (2.9 ma on meter).



firing voltage varied about this much

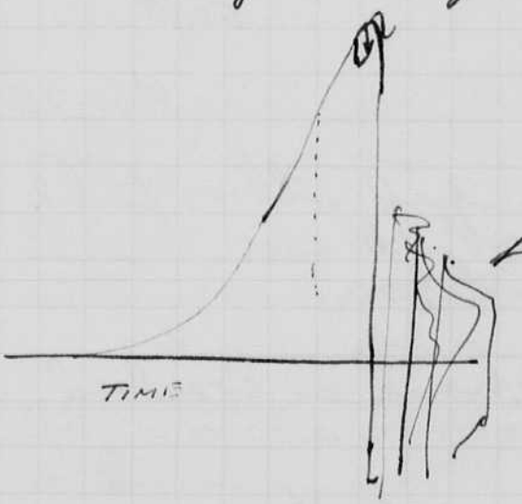
with load on the firing voltage sometimes dropped this low

$115 \times 2 \times \sqrt{2} = 230.4$

920
230
322

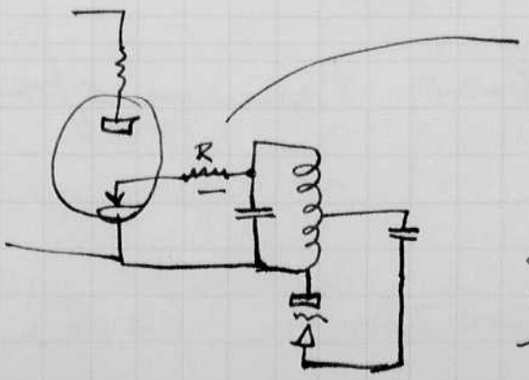
The ignitron was tipped so that the crystal was further immersed in the mercury. The extra load before firing reduced the voltage peak about 20% and firing (without the main ignitron load) became irregular. Fired sometime at 500 volts. Fires better when load is on.

An .03 mf condenser was put across the secondary. Does not change waveform much but delays voltage rise.



firing stuff here now.

I believe this is due to the condenser discharge through the starter over shooting. Reversing brings a positive voltage which fires at a lower potential.



Tried out. 10 ohms is enough to stop oscillations shown above, but 100 ohms operation is ok. Operation is nice and steady. Also seems to fire at lower voltage. 300-400 with out load.

Oct 15 1936

H. E. Edgerton.

A.I.E.E. meeting last night. St Louis (G.E. vapor lamp co) gave the first talk. Nottingham attended with me.

Two new tubes have just been made by Mr. Wagninger. The type is the same as shown on page 44. The active light source is a 2" length of quartz tubing, about 0.4 cm in diameter. It is coiled into a circle and into the anode and cathode at each end.

Oct 16, 36

Tube pumped and filled with 10 cm argon. The other had a leaky seal.
Holds over with 400 ohms 2.25 mf.
Repumped and filled to 18 cm.
Runs ok 350 ohms 2.25 mf. 600
Holds over " 1.25 " 1200
Spits " 2.25 " 1200.

Sewing needle.	1000	f 3.5	Par speed neg	50 ft
	"	"	"	50 ft
	"	"	"	50 ft
Hauser colloid	"	4.5	"	50 ft or 75

Tube began to miss. Pumped other tube and filled with argon at 16 cm.
Missed slightly even at 300.
Changed Mg tubes.
this tube was found to have a cracked seal.

New cathode $BaCO_2$ only used. 16 mm argon used & also ran through the tube to heat 11 (cc) tube.

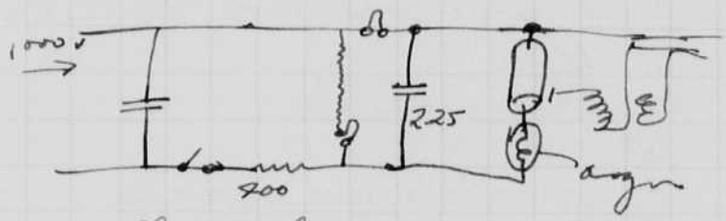
Works ok 600 2.25 - 400 ohms. minimum spark.
" 1200 " "
" " 1.25 "

Photo of Hauser's colloid
f 4.5 Par 1000 1.25 400 ohms. 60 ft.

Spent part of a ft. with Wayne Nottingham taking
Ionization characteristics.

Oct 8, 36. argon lamps also more stroboscopic char.
Movies of Harry Lawrence hitting punching bag.
$\frac{2500}{60} \times 20 =$ about 1000 frames a second.
not so hot.

2.25 mf argon lamp 20 cm. 400 ohms.
The light intensity decreases many fold
as the camera comes up to speed. Does the
hot gas from the tube blow out and
reduce the pressure? Should more
volts be used? Figure out experiment
to show up trouble such as.



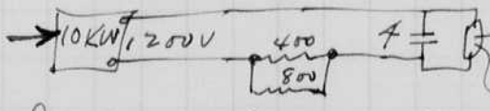
oscillograph

Oct 28, 1936. Pumped tube argon with 2" length of 4 mm
and sealed off with 6 cm argon.

Result a rather grainy tube and filled
with 20 cm argon.

Shipped some after running.

Retubulated and repumped. Treated with
following circuit



The electrodes and guard became red hot.
Sealed off with 1/4 cm argon.

This tube worked in a satisfactory
manner at 1200 flashes per second
in the above circuit for a few
series of flashes (1 sec in duration).
Then it started to miss even at 600
cycles/second. The gas when excited by the

spark coil appears orange tinged showing impurities.

This tube has an acting length of about 3 or 3½ inches of 7.9 mm (inside diameter) quartz tubing. The ends are 11/16" in diameter

A new tube was ordered today with a 1½ inch length of 3 mm I.D. Quartz tubing as the acting length and with tungsten electrodes.

Mr. Tucker is going to work with Prof Hauser as a special research assistant. I had lunch today with them and discussed problems to be done.

Oct. 30. 1936. H. E. Edgerton.

That tube mentioned above was made and pumped but the seal broke. It runs ok with 1200 volts at one atmosphere. 20 mf was used. Very bright.

Nov. 5, 1936.

Showed new reel (just assembled) last night to the M.I.T. faculty club.

Yesterday two men from the Jenstell Co were here, Mr. Driggs, F. H. and ?
Discussed auto ignition system.

Nov. 13, 1936.
H Edgerton.

Nov 9-10-and 11 was spent on an inspection trip with W. Nottingham and ten students. We left at 11 am nov 8 Sunday. Nottingham and I had supper with Egmont Arens and wife 42 E 78 St. Dr Mackay and Mr. Bernstein and wives came in after supper and we ran the latest high speed movies.

Morning Nov 9 Cooper Hewitt Co. Mr Mailley, Mr. Brown - Sodium lamps - Minnisota
Seals & Hg lamps. Lyman Johnson.
neon Count?
Circuits St Louis
Osc in Hg tubes. Kenty.

Afternoon - Bell Labs. Mr. Lacle.
Wilson
Sears. etc.

I returned to mary Ellen's house 211 Summit ave Summit. N. J. & I had dinner with Mrs Dudley Sevin.

Morning Nov 10 with Thomas Wood, and De Rochmont of Time, Life & March of Time.

aft. I went to Steicher's Lab on 139 east 69th St. and saw the work that he is doing with color photography.

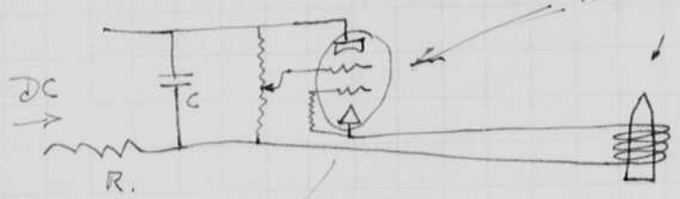
Morning and all day Nov. 11 at R.C.A. Radiotron in Harrison N. J. Saw B J Thompson, Dr Miller Mr. Ritter? Dr Chase Shaw. Dave Langmuir, Schaeffer Wagner and others. Showed the High speed movies at 7:30 p m to a large group.

Nov 13 1936

H. E. Edgerton.

Apparatus for removing
metalic particles from
runners and from apparatus.

A condenser discharge through a coil and a rectifier produces a very strong force on a magnetic particle because of the large momentary magnetic field. The discharge can be periodic using circuits which have been used in stroboscopic work. The strobotron circuit which we developed for Defrost should serve satisfactorily also.



Strobotron,
Thyratron or large Hg lamp.

The series of jerks excited by the magnet should produce a strong force on the magnetic particle, more so than possible with a steady pull by a dc coil.

I also believe that the size and cost of the apparatus is low enough to make it available to many doctors and to small manufacturing companies.

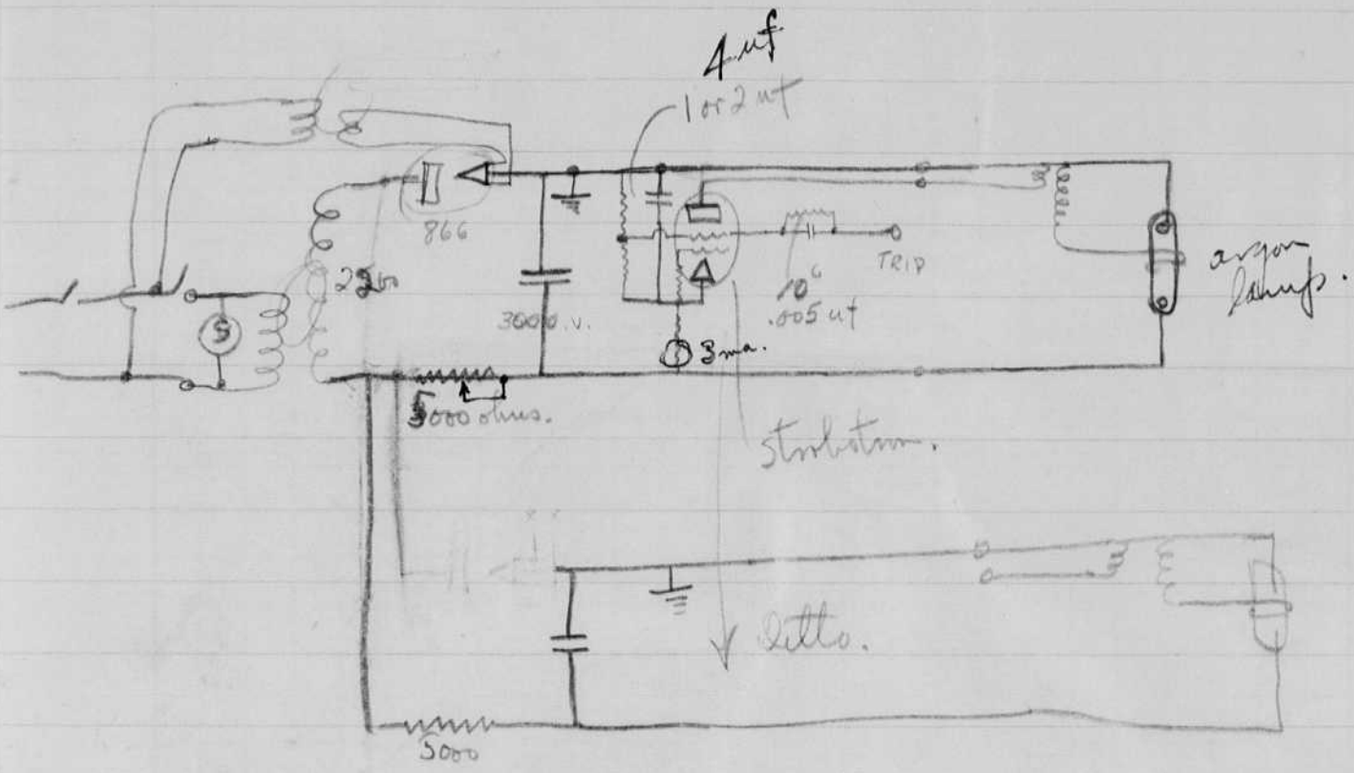
Explained to Me by H. E. Edgerton
Nov 14, 1936 Kenneth J. Germeshausen

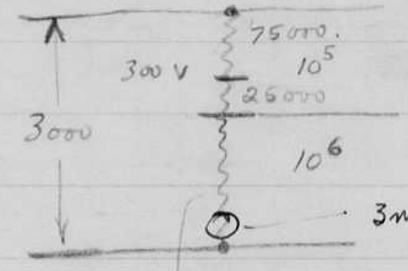
This above was discussed at lunch with Horton on Jan 20 in Walker when Germs and I were there.
Jan 21 KJG

Explained 11-14-36
H. E. Edgerton

Plans for new Spark-Argon apparatus

Drawn on Nov 7 1936,

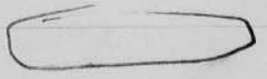




.003000

3000 3000 / 10^6 1 watt.

5 200,000 ohm, 2 watt resistors.



20 mf. 3000 volts.

Nov 15 1936
H. E. Edgerton.

Last night I worked with Mooney on his thesis problem after having him out to dinner. We had a .30 caliber rifle from the R.O.T.C. and some armor piercing ammunition. The experiments were not entirely successful due to the fact that the amplifier was microphonic. Also I accidently shot through one of Mooney's trip coils.

A student named Townsend is going to work with the mercury tube rectifier using the external grid to start the action with no sources of e.m.f. in the plate circuit: I outlined the problem to him at some length about two weeks ago and listed a series of experiments for him to do. He is now reading Mueller's theses and also a laboratory report by Howard.

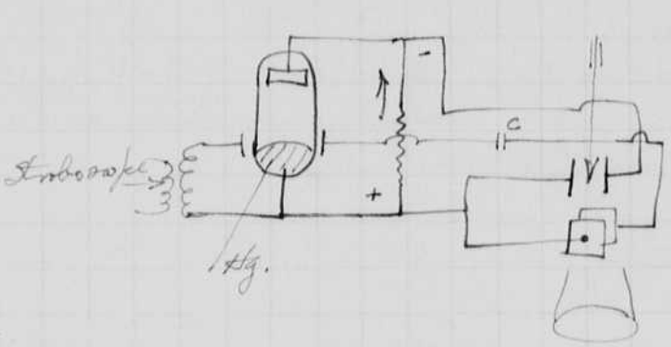
He is setting up a thyratron oscillator to put high voltage on the grid of the Hg tube and will work in the high-voltage room 10-180?.

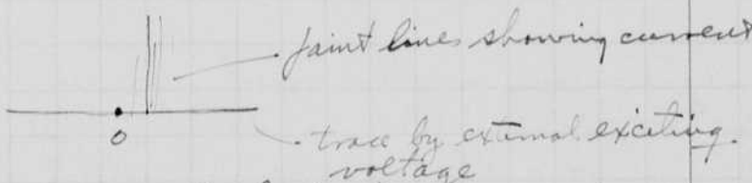
As I recall the experiments discussed are:

1. Freeze the liquid Hg at the bottom of the tube to see if the emission current stops.
2. Vary the gas pressure, argon, neon etc to find effect.
3. Vary the anode cathode spacing.
4. Vary the cathode area. (glass-Hg contact distance)
5. Vary the glass thickness.
6. Investigate the effect of frequency of the disturbing voltage to note if wave motions of Hg are important.
7. Put DC on external grid and shake tube with variable frequency.
8. Find regulation etc of tube, i.e. volt-amps. char.

9. Try to build tube with other metal than Hg.
(this may not work with solid metal - see 1.)

10. Investigate instantaneous currents from anode-cathode and correlate with grid voltage. A series of experiments were made last year on this, but I could not find record when talking to Townsend last week. As I recall, the external exciting voltage was put on one set of plates and the current (drop in a resistor) across the others.





This experiment indicated that the current was erratic and that it came at the zero or slightly positive of the a.c. on the external grid.

11. We also discussed possible regulating schemes for keeping constant current or constant voltage on the output by controlling the external exciting voltage by the output.

Nov 21 1936
H E Edgerton

H T Day, New York, came on thurs Nov 19. for the spark machine 3 mf 16000 volt.

On Nov 17 took 2½ doz 9×12 gas Tucker photos of Jans for Peters (GE job). Carter helped by this while learning how to run the camera.

Studied Jans again today with Peters and took more photos. See GE Book.

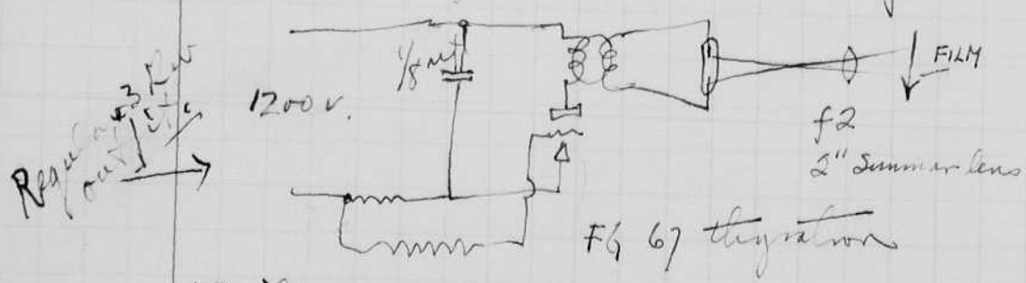
Nov. 26, 1936.

Prints made of photos (Peters) made on the 21st. These show some new results and peters wants some more motion pictures.

I set up the Motion picture apparatus last monday Nov. 23. d. Ran through a film on the G.E. Jan (narrow blade) on the 24th.

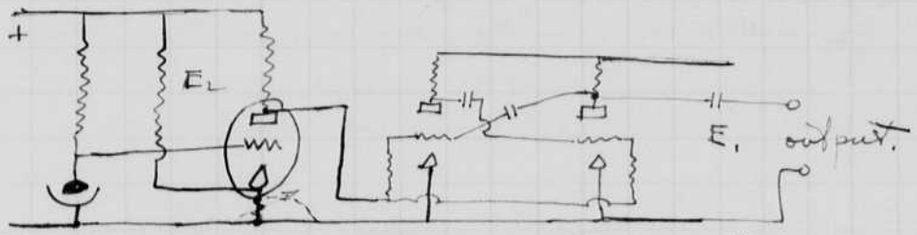
Prof. Henry has been busy inventing circuits to use in a photoelectric engraving machine. He has arranged for us to build a light source for the thing. A few tubes have already been built as below

This is filled with argon at 15 cm. the circuit for flashing is the following.

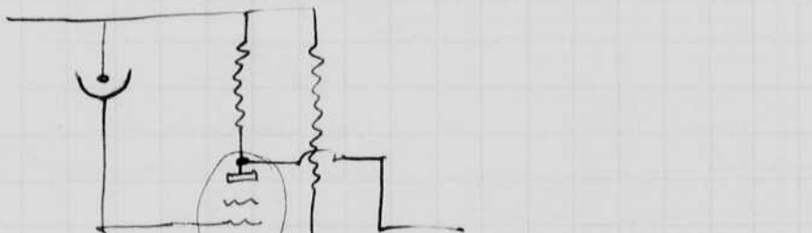


Tests run at 150 cycles/sec. Sound recording film. Exposure ok at 1:1 reduction size.

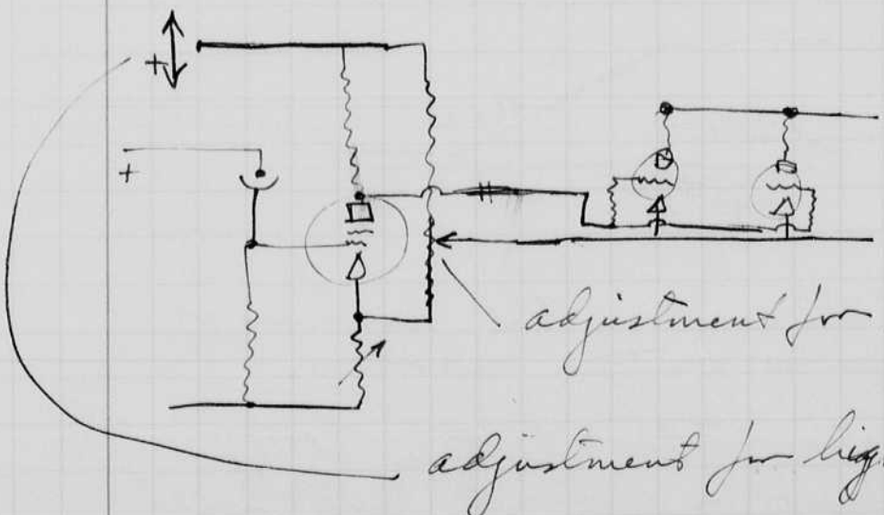
Varney discussed his ideas with me at some length yesterday and called me on the phone twice today about additional methods of getting the photocell to put dots on the film. Variable spacing of black dots for the light parts of the engraving but light dots for the dark. The method of doing this with a photocell and flashing lamps may be bothersome.



this circuit produces a frequency that decreases with light.

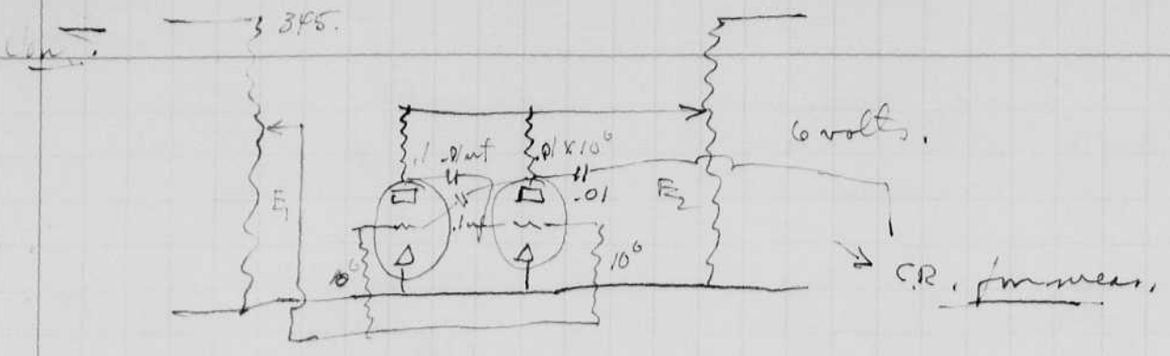


this circuit produces a frequency that increases with light.



2000
10

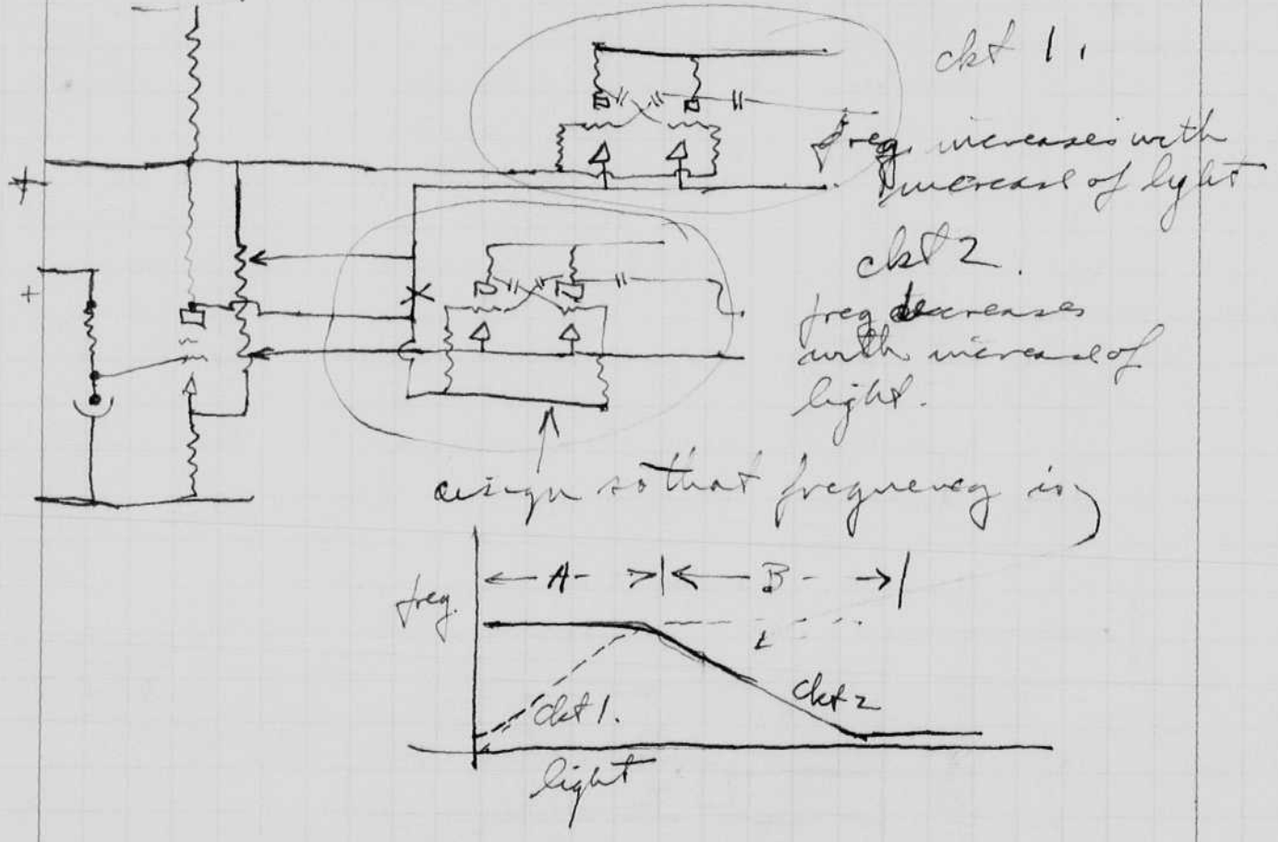
200-1.



$f_{reg} = \frac{E_1}{E_2} \frac{1}{2RC}$?

$= \frac{E_1}{E_2} \frac{1}{2.2 \times 10^{-6} \times 10^6} = \frac{E_1}{E_2} 5.$

$\frac{2000}{5} \times 5 = 2000$ cycles.



Circuit 2 will control the flashing of the Strobowipe lamp that puts on the marks.

Circuit 1 will prevent the starting of the strobo wiper lamp in region A but will be in operation in region B.

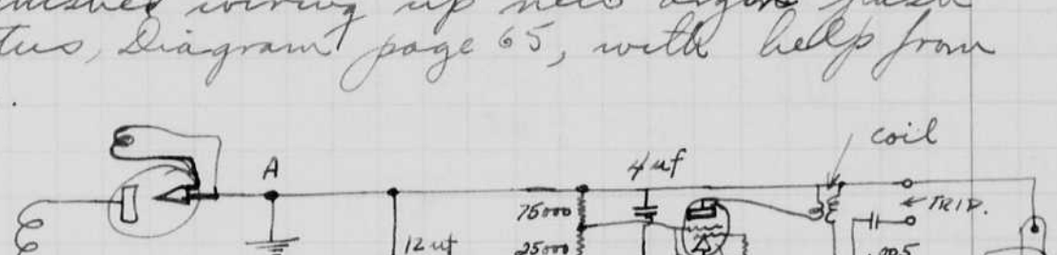
Nov. 30, 1936.

Hardy came in on Saturday Nov. 28. and explained at some length the circuits that he told me about on Thanks giving over the phone. Germeshausen is building a special glow lamps for this job for producing puts!

Martin of Allis Chalmers co was here today to deliver a lecture upon mercury arc rectifiers.

I worked this afternoon with Mr. Cheney of the M. E. Department, trying to take photographs of a pelton wheel. Difficulty was experienced in photographing through wet glass.

Finished wiring up new argon flash apparatus, Diagram page 65, with help from Kiethley.



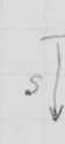
Circuit right of A.B. repeated for several

Dec. 2, 1930.
Harold E. Edgerton.

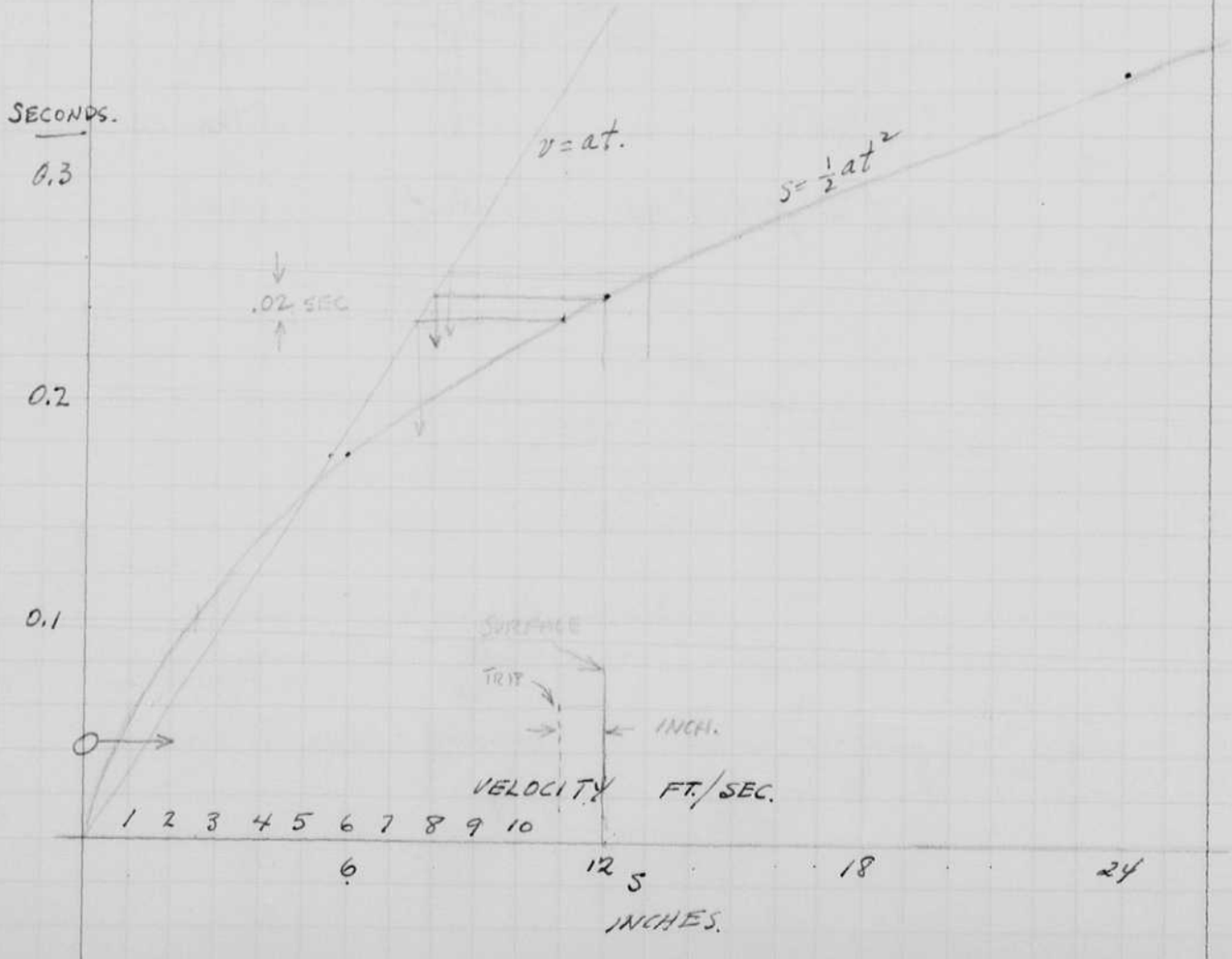
I worked last night with a student named Kiethley taking photographs of milk drops. Leica camera used f 18.5 new Spark machine used diagram on page 71. For some of the photographs the lamp was in a reflector. In others it was not. Distance to tube from drop about 4 to 6 inches. Photocell trip of light beam used. These pictures look good.

Mr. Pettingill and Mr. ? came in today and I demonstrated the 548 Stroboscope.

Calculations for time delay apparatus to be used in photographing splashes.



$$s = \frac{1}{2} a t^2.$$

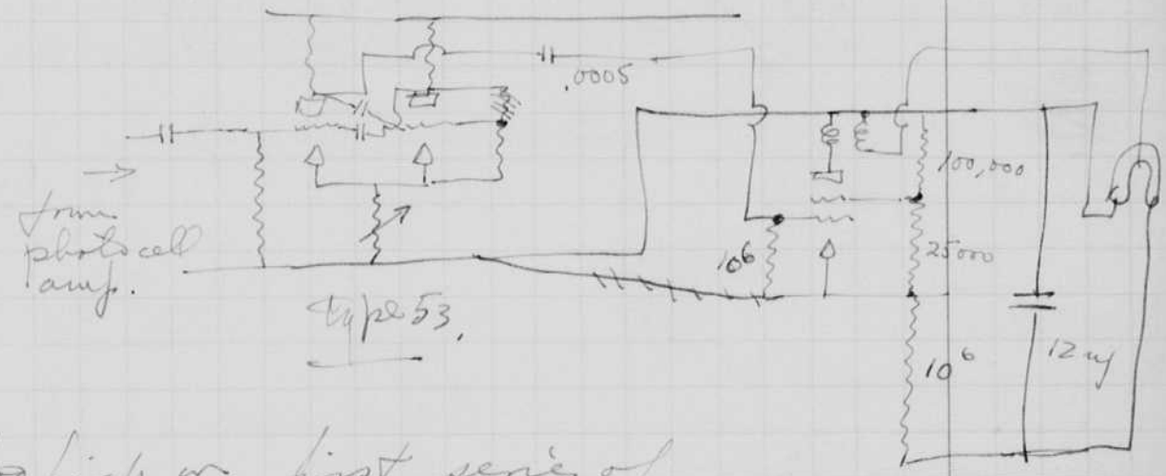


Dec. 6, 1936.
H. E. Edgerton.

Set up water dropper on the crane in the Dynamo Laboratory and took closeup photos of the drops after they had fallen 24 ft 10 inches. The Leiga camera was used. $\frac{13\frac{1}{2}}{16} = \frac{27}{32}$
with lens extension so that
1 3/8 inches on the film
was of 27/32 on the subject.

$$\text{magnification} = \frac{1\frac{3}{8}}{27/32} = \frac{11}{8}\,\frac{4}{27} = \frac{44}{27}.$$

Electrical apparatus about the same as used on Dec 2. amplifier hookup below.



Drop too high on first series of pictures. f 18.

36 pictures taken at f 12 with lower timing of flash. ok. Show different forms!! We thought the form would be constant!

Dec 7, 1936.
Ht Ekquity. Wt. of Water drops from
Kiethley Lyon drop pipet used yesterday.

Rate 10 drops 12.8 seconds
10 " 15 "
10 " 16
10 " 15
10 " 19 - 16.5

Filled to 10½"	7	nozzle adjusted	16.4914	11 "
6½" "	6		16.3994 .0920	11 sec for 10 drops
6½" bent.	5		16.3044 .0950	25
	4 " "		16.2129 .0915	22 " " 10 "
	3 " H_2O		16.1210 .0919	20 sec for 10 drops
	2 drops H_2O		16.0284 .0926 rate	17.5 sec for 10 drops.
? 7 or 8"	10 drops H_2O		15.9353 .0931 rate	19 - 16.5
	wt of bottle		15.8417 .0936	

10½" 9 6711 .0899
8 16.5812 .0898 50 sec for 10 drops.
4914

Dec 7, 1936.

List of Material for New Argon Spark Flash apparatus see page 71 for ckt. also below.

1 Transformer Pri. 115 Sec. 25v 5amp. for 766
1 " " " 3000 v. 10 ma.

2 condensers 12 mf 660 ac volts.
2 " 5 mf 400 volts D.C.
2 10,000 ohm 50 watt resistors

1 - type 866 rectifier

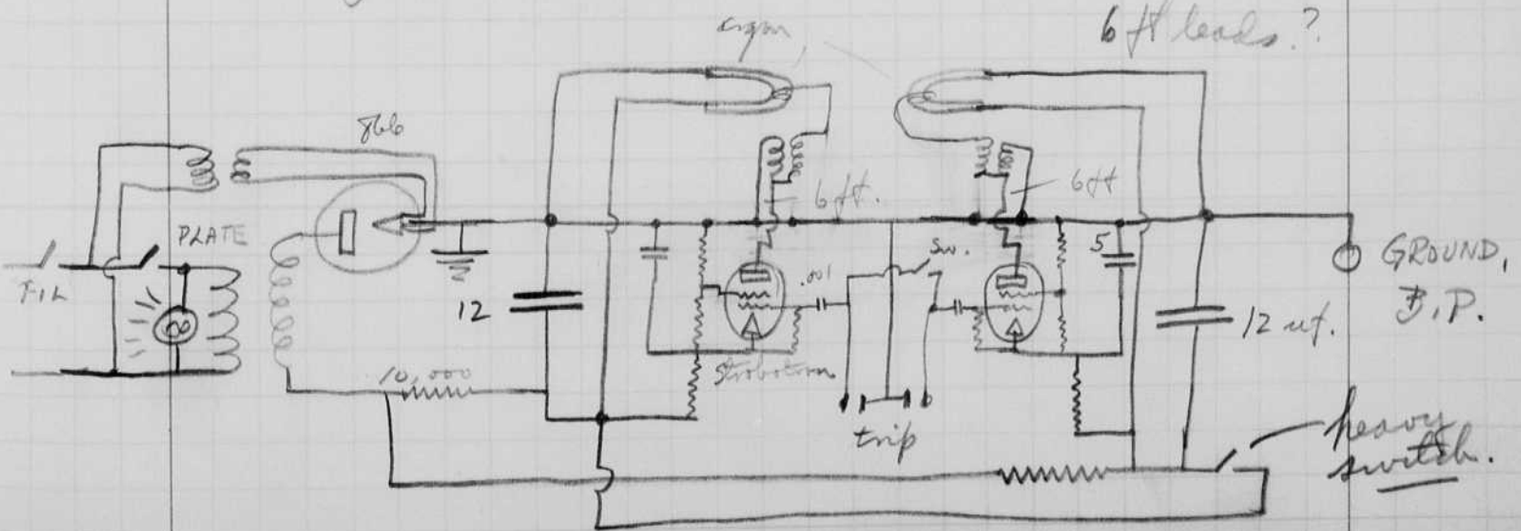
1 - Strobotron

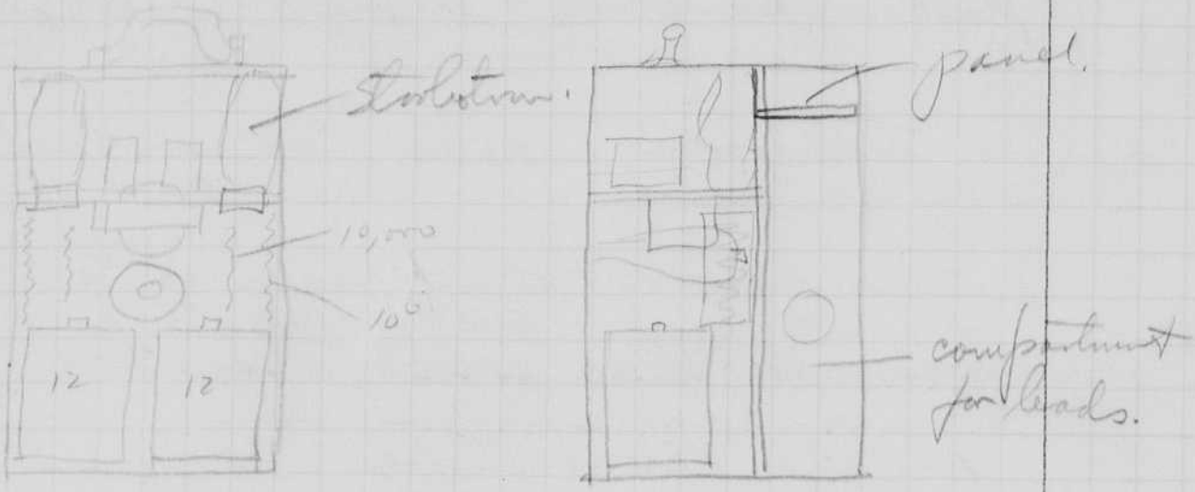
2 - 4 prong sockets

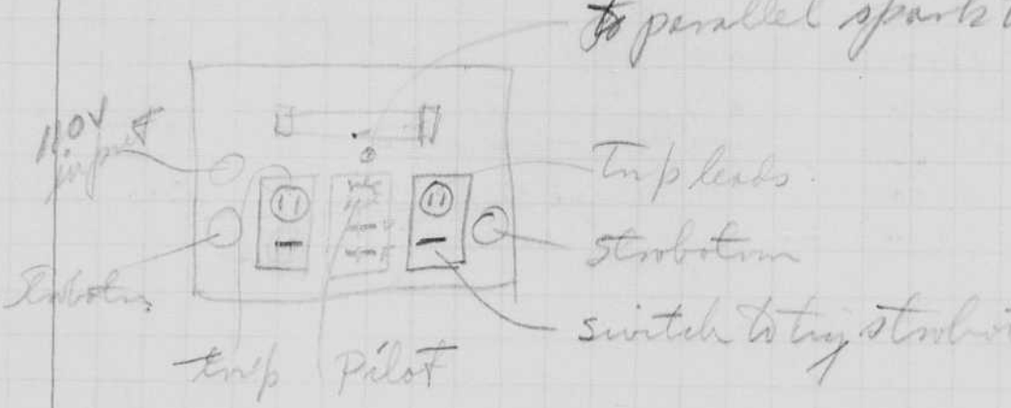
10 - 0.2 x 10^6 ohms 2 watt resistors
2 - 25000 " "
2 - 75000 " "
2 - 50,000 " " adjustable
2 - 10^6 ohms " "

2 - .001 mf condensers

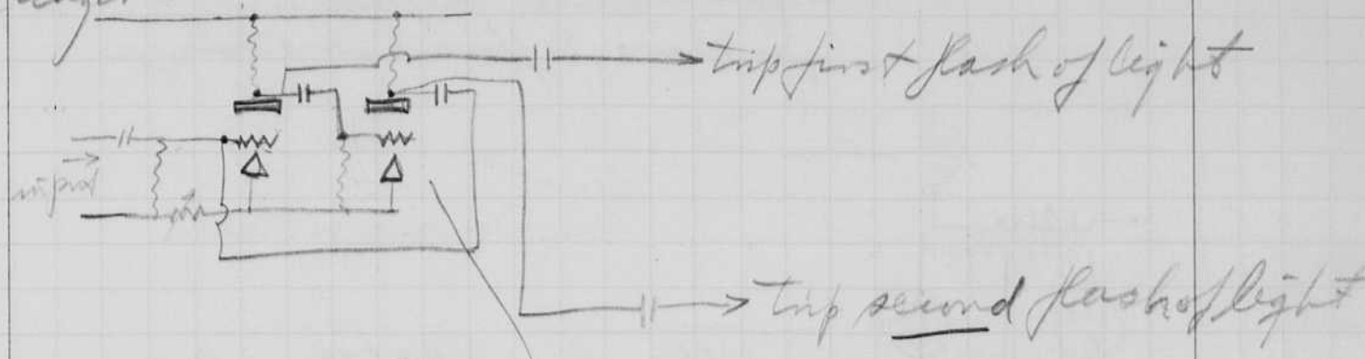
1 Double outlet (Spark coil & trip leads).
1 Double switch arrangement with pilot
1 - Paralleling switch for high capacity.
1 - " " Double trip.
2 - push buttons.




Storbotron.
panel.
10,000
10
12
12
compartment for leads.


to parallel spark trip.
110V
Trip leads.
Storbotron
switch to trip storbotron.
trip
Pilot

Dec 7, 1936 Time delayed flashes.
H E Edgerton

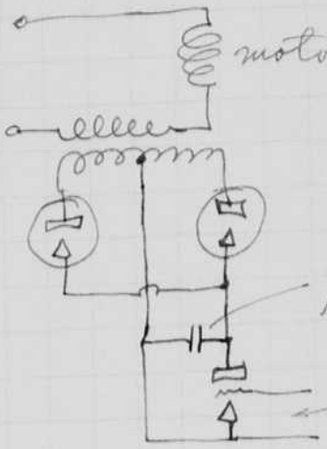


This method should be useful for measuring velocity. It will give two exposures on the same film at a known interval of time apart. The method can be stretched to more than two photographs

The second tube above may need a capacity from plate to cathode in order to slow up the voltage build up rate when tube no 1 snaps on, to prevent the early flashing of lamp no 2.

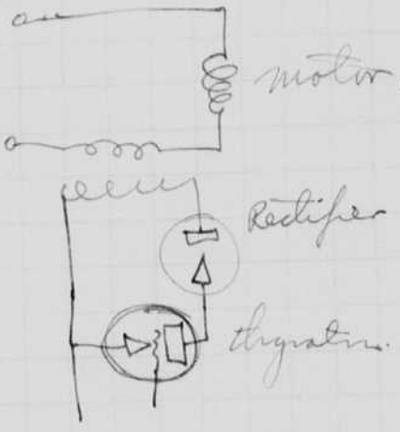
Dec. 11, 1936
Harold E. Edgerton

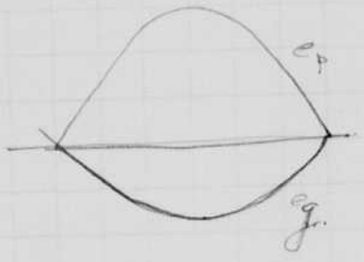
Motor control method
for new Differential Analyzer.

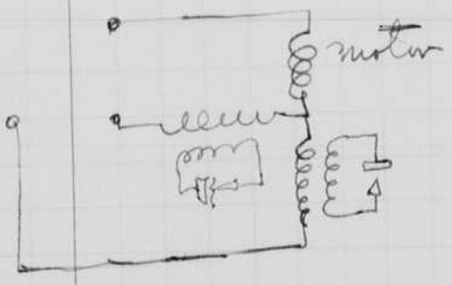


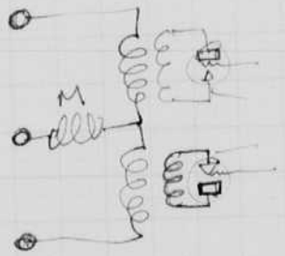
possibly not needed if thyratron is ~~needed~~ used. Condenser is required with thyratron.

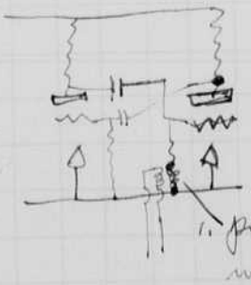
Ideal Starting Characteristic







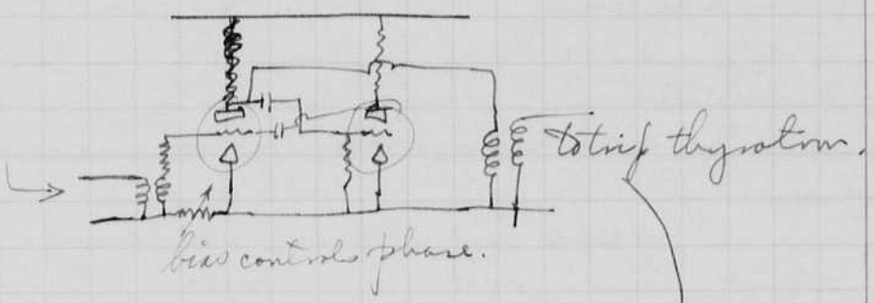


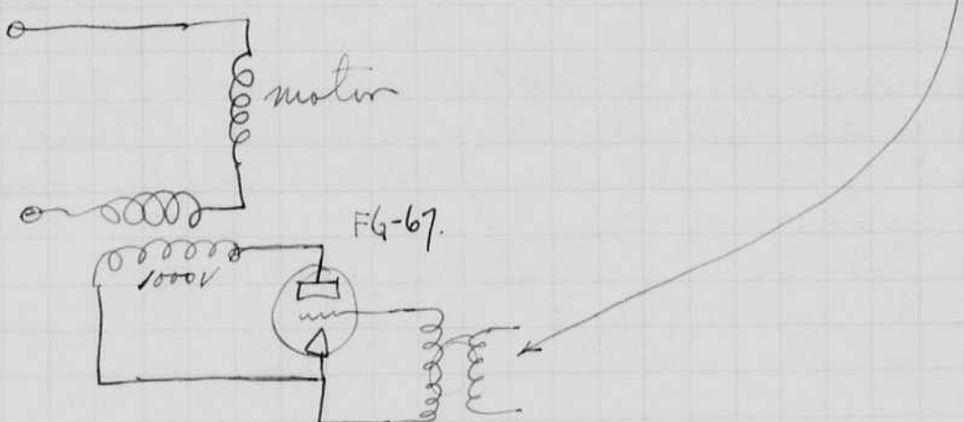


1. put bias in series with input to grid.
2. Use R and C to ~~run~~ lower than 60 so that control will be ~~more than~~ 180 degrees or

3. Introduce 90° phase angle into the input.

control part of cycle.



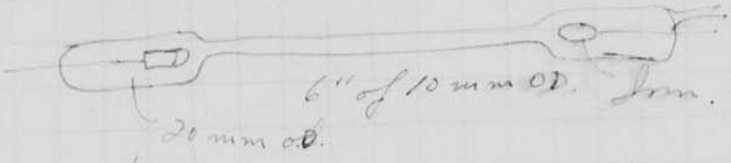


thyratron with positive starting characteristic

After drawing the above in the evening I went over to Sam Caldwell's house and discussed the above scheme with him and with Jaeger. Jaeger plans to hook up multipulse to apparatus to dribble a mercury thyratron.

Dec 12 1936

I had two tubes made of the following design.



Pumped and filled with argon 1 atmosphere. 3 mf 15000 volts blew them both up! Shattered the glass completely into small parts. Mr. Popkin and Price saw this.

I used the same seals and electrodes in a tube about 14 mm OD. 9 or 10" long. Again 1 atmosphere of argon. Works ok.

Camera setups. of Price & of Popkin. Light in cylindrical reflector 6" from object. Camera f 11 Verichrome film. exposure 0.2 s.

Dec 13 1936.

Spent all day with Kiethly taking photos of the drops in the elevator shaft. The dropper was on the elevator, dropping through a hole in the floor. Pictures were taken with the elevator at 5th 1st 2nd 3rd 4th 5th and 8th floor. The camera was at the level of the basement floor. A photocell method of tripping was used. From the 8th floor the drops were in a 8" circle. Two photos taken to get 2 pictures of drops!

The drops do not break up in falling this distance. Wt of drops about 0.9 grams.

H.E.Edg.
Dec. 14 1936

Germeshausen and I spent the afternoon at the Raytheon Co talking with Mr. Marshall about possibilities of cooperation with the strobotron and the circuits that we have developed principally for welding control. It may be possible to work out a method whereby we are also consultants for them in all engineering work and also receive a royalty for sale of strob tubes and other apparatus. Discussed Hg pool tubes with external bands with P. Spencer. Also saw Bertram after visiting the factory.

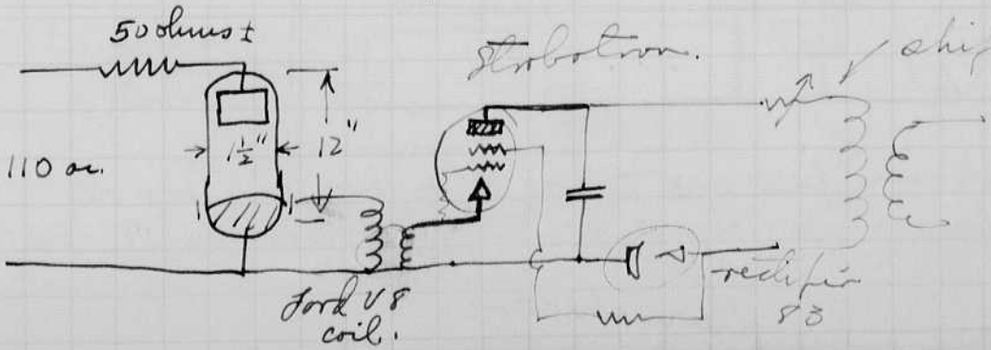
Dec 15 1936
H.E.Edgerton.

I spent the morning in Mr. Rines office with Mr. P. Friedman and Mr. O.H. Eschholz of the Westinghouse Company discussing the synchronous motor control system of angle switching. Invitation to visit Pittsburgh

Had supper at the home of Robley Evans and then took spark photos of Mr Lamie? hitting a table tennis ball. Newton Center.

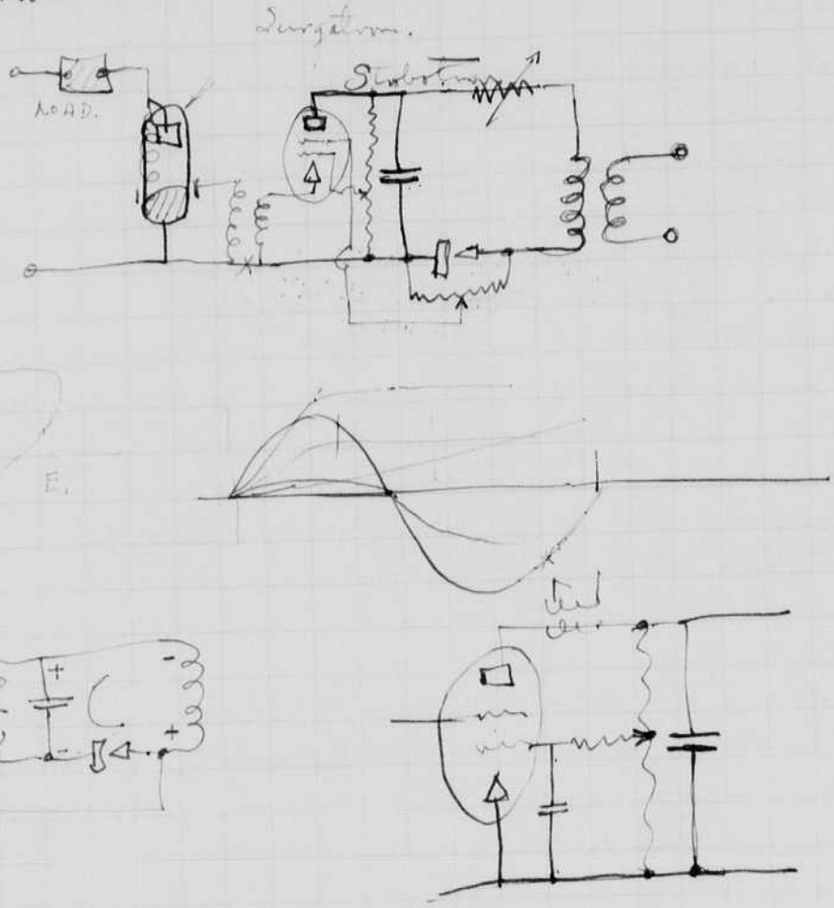
I talked to Jaeger and Caldwell again today about motor control schemes for speed control. The Hg pool type tube was discussed as a possibility for driving the motors instead of the tubes they are using. A Strobotron will also be needed to map on the Hg tube.

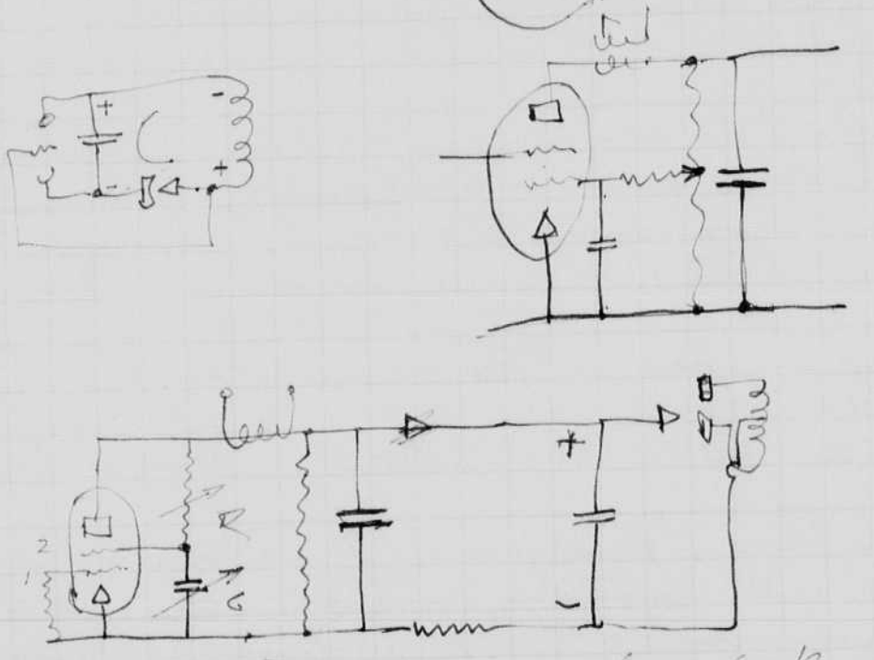
a Hg tube with Strobotron control has been on life test since Dec 11 1936 Days only.



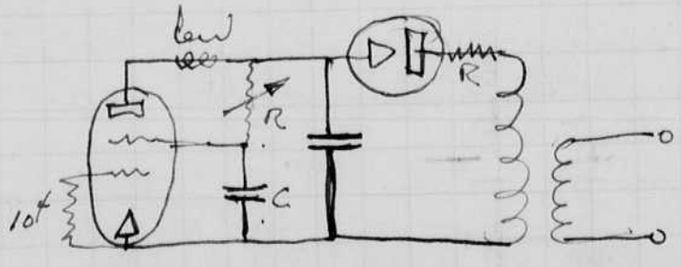
Dec. 12, 1936.
H. E. Edgerton

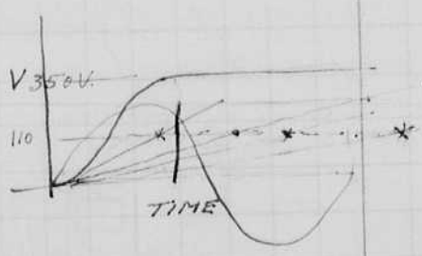
Phase shift control for Hg-Pool tubes.





Grid 2 voltage goes to zero at each flash due to arc condition in tube. Build up of voltage on grid 2 is determined by the RC combination indicated above.





Circuit Explained
12-16-36
Herbert E. Grier

RC should vary from .002 to .02 for proper phase shifting

Explained 12/16/36
Germeshausen

Let C = .01 mf $R = \frac{.002}{.01 \times 10^{-6}} = .2$ meg.

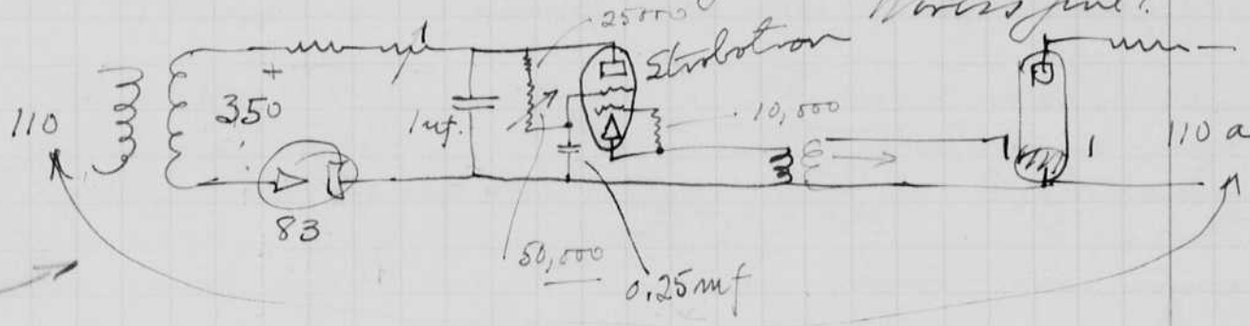
and $R = \frac{.02}{.01 \times 10^{-6}} = 2$ meg.

try C = .1 mf. then R varies from .02 to .2 megohm.

or R = 70,000 ohms. $C = \frac{.02}{70{,}000} =$

try C = 0.25 mf. and R = 100,000 ohms.

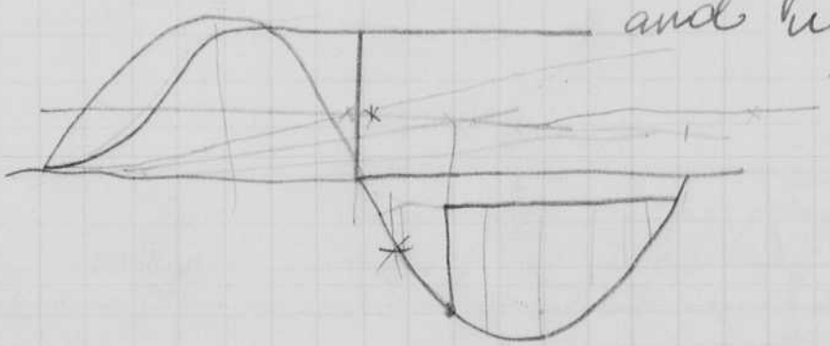
I set up and tried the following circuit Works fine!

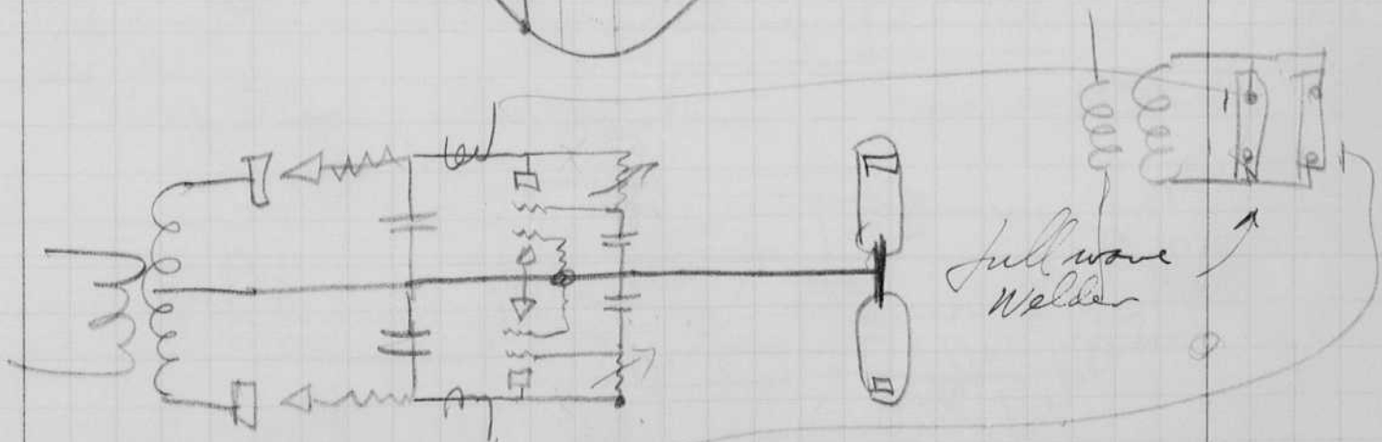


Seen in operation and operation explained and understood.

G E M Bertram
12/17/36
/16

F. H. Gross 12/17/36.
/16



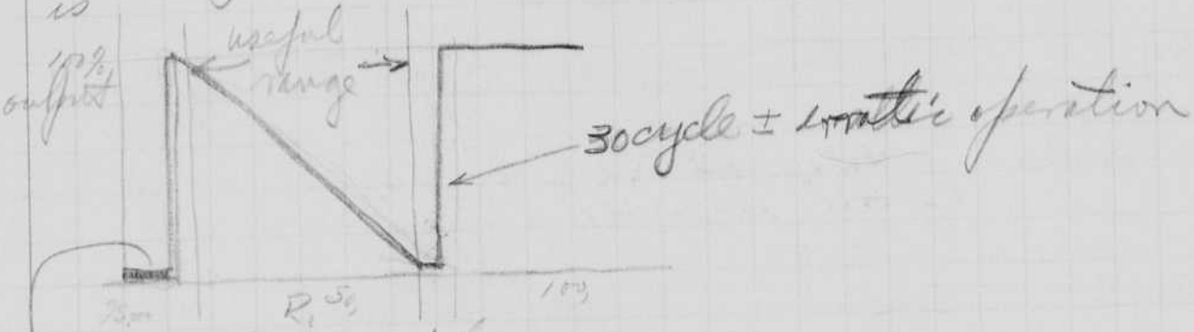


A Strobotron and the circuit above was given to Bertram and Gross to set up at Raytheon Equip. Co.

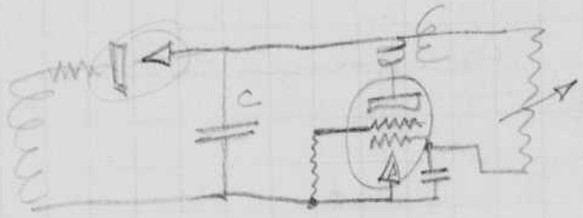
16

Dec 17 1934 Cont.
Ignitron

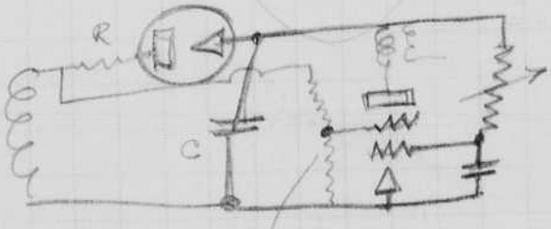
The circuit for phase control on page 83 has a disadvantage due to the form of the output curve vs Resistance, which is



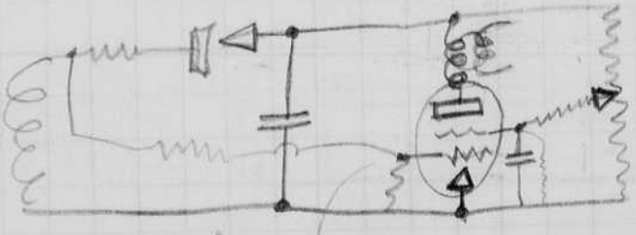
Control resistance off single shot tube gives before voltage is positive on Hg pool tube.



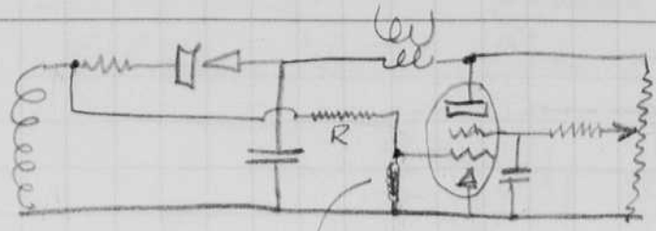
this may be steadied in operation.

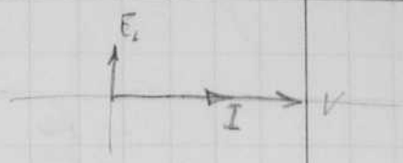


put ac on outer grid.

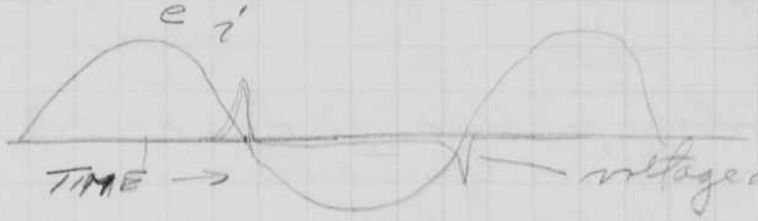


this probably will not be needed.

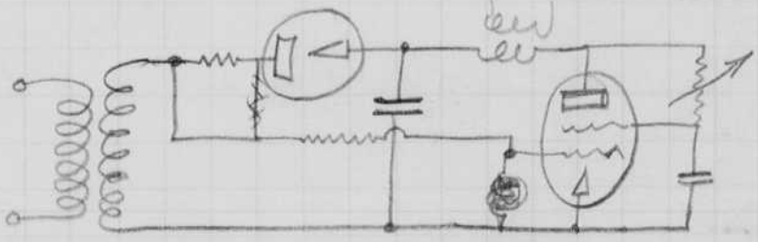




Saturated core reactor to produce a peaked voltage at the end of the cycle. Resistance R limits the flow of current through the choke

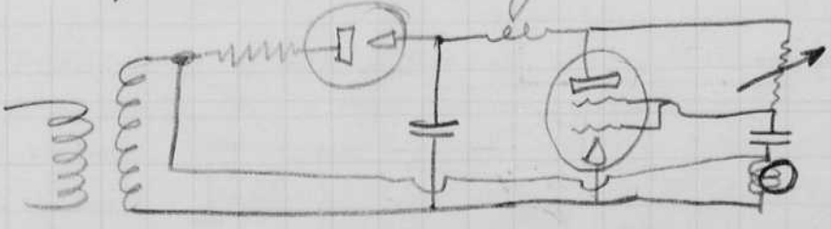


This peaked waveform will produce a negative surge of voltage on the inner grid and fire the thyratron at the zero of the cycle, making the operation positive in case the time constant is such as to not fire the tube. Overcomes the erratic operation mentioned on page 84.



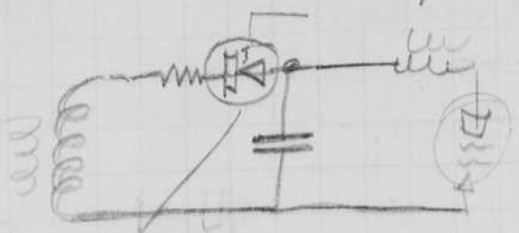
It probably will also fire the first part of the cycle? Possibly not depending upon the magnitude of the peaked voltage and the voltage on the outer grid at the zero of the cycle.

Works ok also for three element tube.



Explained 12-17-36
Herbert E. Grier

Dec 12 16 1936 cont. Welding timing circuits



1. Grid controled rectifier thermionic type to control time on,

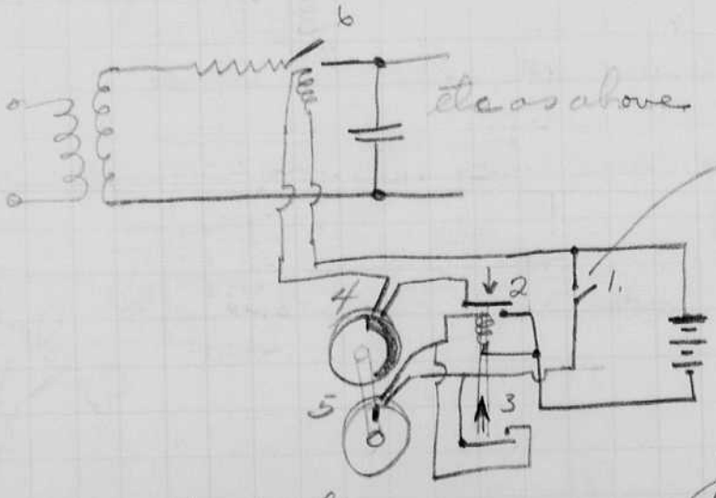
2. Switch in this lead operated by a rotating contactor. 2 to 6 cycles.

2 cycles = 1/30 sec.
900 rpm ~~rps = 60~~ 7/30 sec.
600 "
300 " 6/30 = 1/5 sec.

Bodine Synchronous motor 1800 with gear drive 6:1

2 cyc 1/30 sec = 2/12 th rev.
3 cyc 3/60 " = 3/12
4 " 4/60 " = 4/12
5 " 5/60 " = 5/12
6 " 6/60 " = 6/12

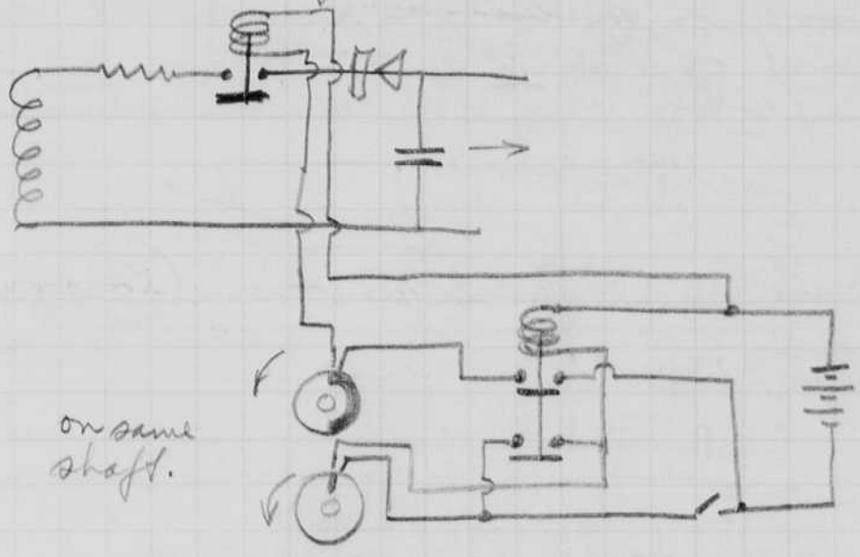
} Brushes.



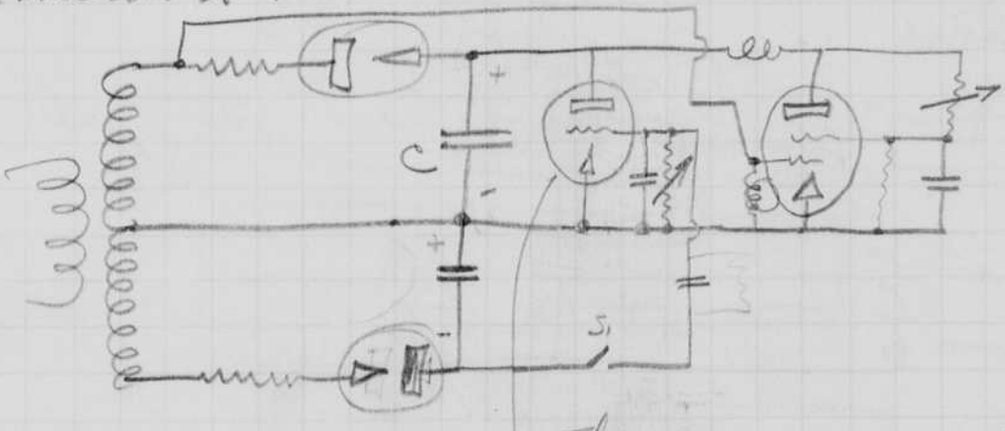
which pulls 6 shut for n cycles as per disc 4.

cont.

Redrawn sketch of same



3rd method.



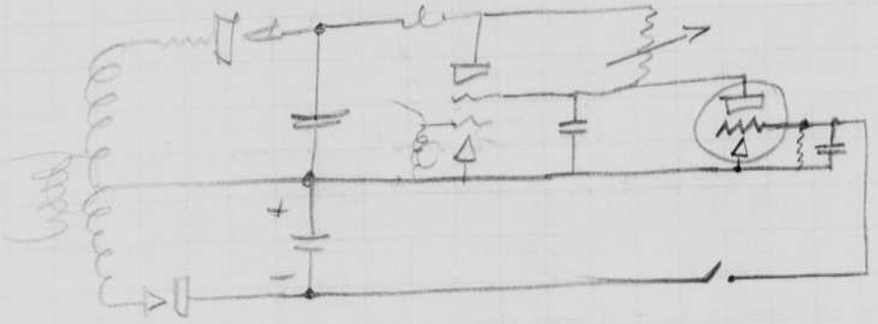
This is a vacuum tube that has zero potential on the grid when S1 is open.

The output of the condenser current is thereby shunted so that the stroboton does not fire.

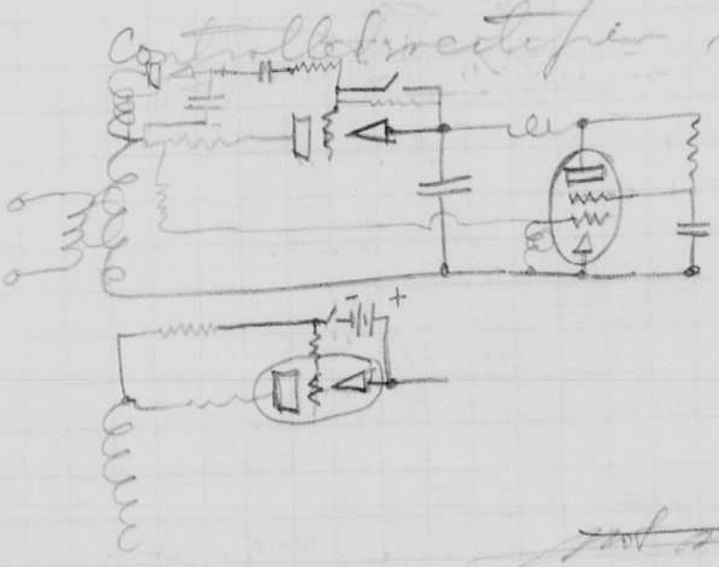
Closing the switch S1 puts a large negative bias on vac, triode and this takes off the heavy shunting plate current allowing the strobotron a chance to fire. The charge leaks from the grid condenser at a rate determined by the resistance shown across it. Eventually the vac triode again shunts the condenser and stops the strobotron.

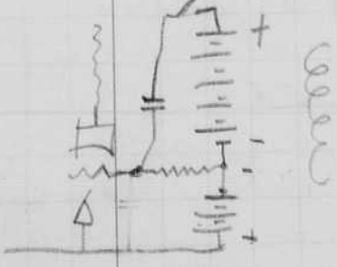
Dec 16 1936 Cont.

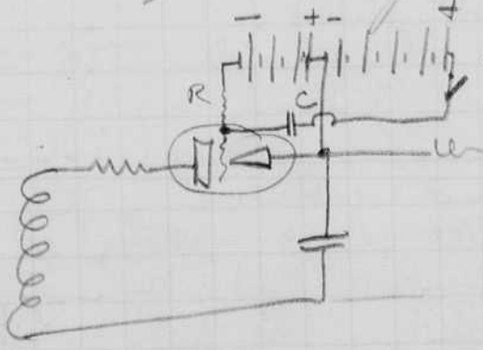
A modification would be to work a similar circuit in the grid of the strobotron & put a tube in the strobotron.



Operation same as previous page. If the triode passes out due to life it will turn the strobotron on all the time.

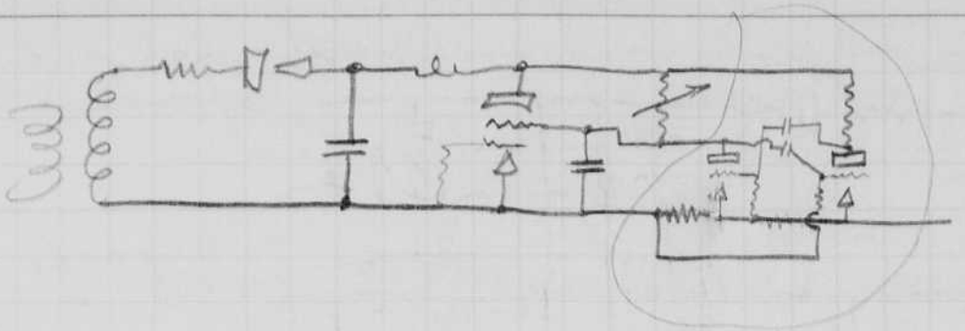




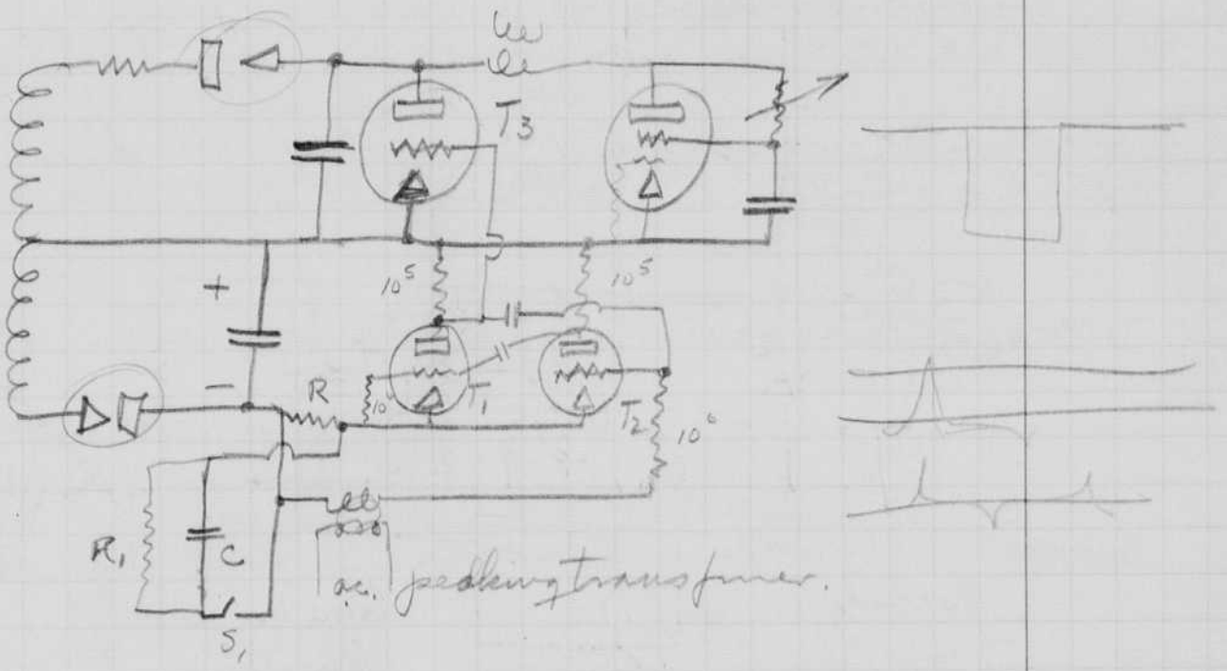


close switch puts + voltage on grid for certain length of time. depending on R.C.

Cont.



biased multivibrator to hold the circuit off for a definite time.



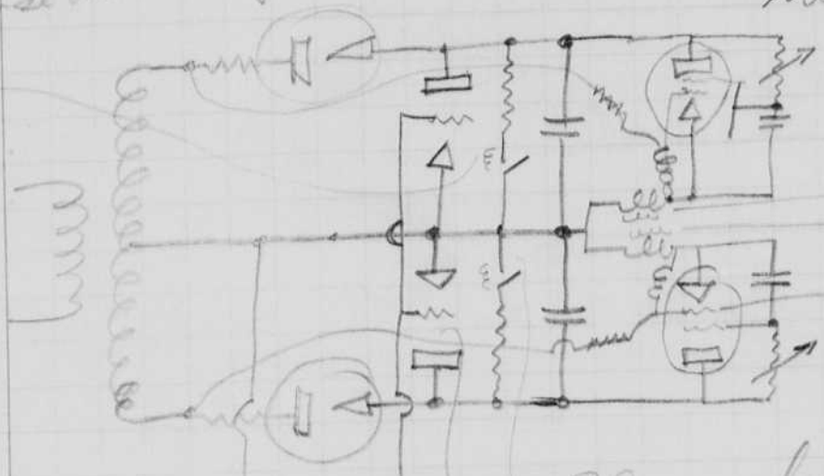
Close S_1 charges C from bias circuit thereby reducing bias to value nearer cut-off value, making it possible to turn on T_2 at the correct part of the ac cycle. Relaxation oscillator (one cycle) then results which puts zero bias on T_3 for a known time. C is charged in 1 cycle of the ac so that the relaxation oscillator does not operate to again. R_1 bleeds C when S_1 is open, preparing for the next flash.

The feeding transformer may not be needed in this type of circuit.

This circuit works ok for the full wave arrangement. Both triodes T_3 are given zero bias by the same multivibrator.

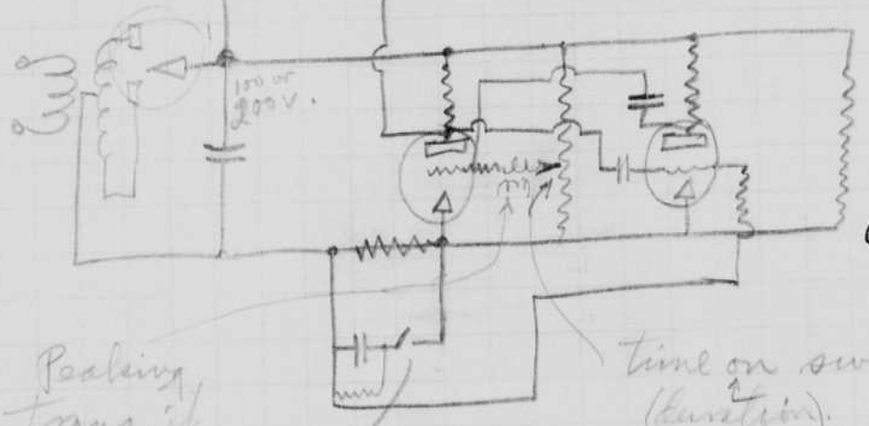
Cont.

Inverse time relay to short output in case of more than the desired operation



Relay or hand switch to turn off trip circuit.

203
250
etc.



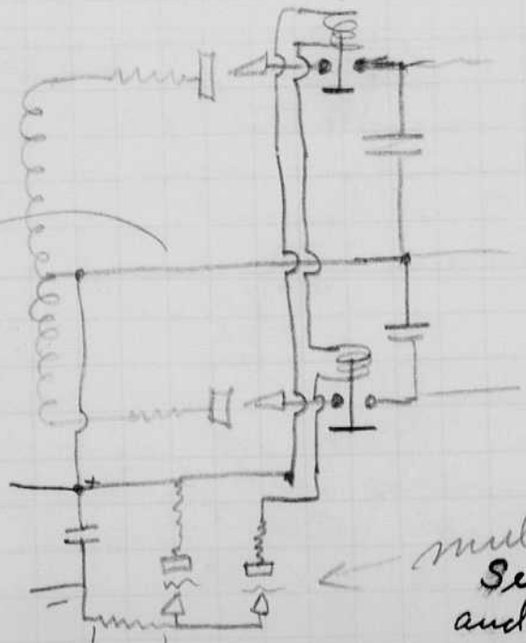
Explained 12-17-36
Herbert F. Ives

These circuits explained to me 12/17/36 by Stray

Peaking trans. if needed.

Start switch.

time on switch. (function). this probably should go to taps on the resistor to give 1, 2, 4, 8, cycles. another way is to change the capacity in the grid circuits as per above →



one relay could be put here in place of the two.

for this circuit a high speed relay is directly operated by the plate current.

multivibrator same as above.

Seen in operation and explained and understood. 12/17/36 C. E. Tucker.

Dec. 19, 1936.
H. E. Edgerton.

Morning spent taking movies at 200/sec of cloth shrinking machine model brought to the lab by. Mr Sanford Cluett. } Cluett, Peabody & Inc Troy N.Y.
" Schriener (?) }
" Porter. Roberts, Cushman, etc.

#1.	4.25 mf	1200 V (3 kw outfit)	f 2. overexposed.
2			f 4.5 " "
3			f 6.3 Angle of light change
4			f 6.3
5			f 6.3.

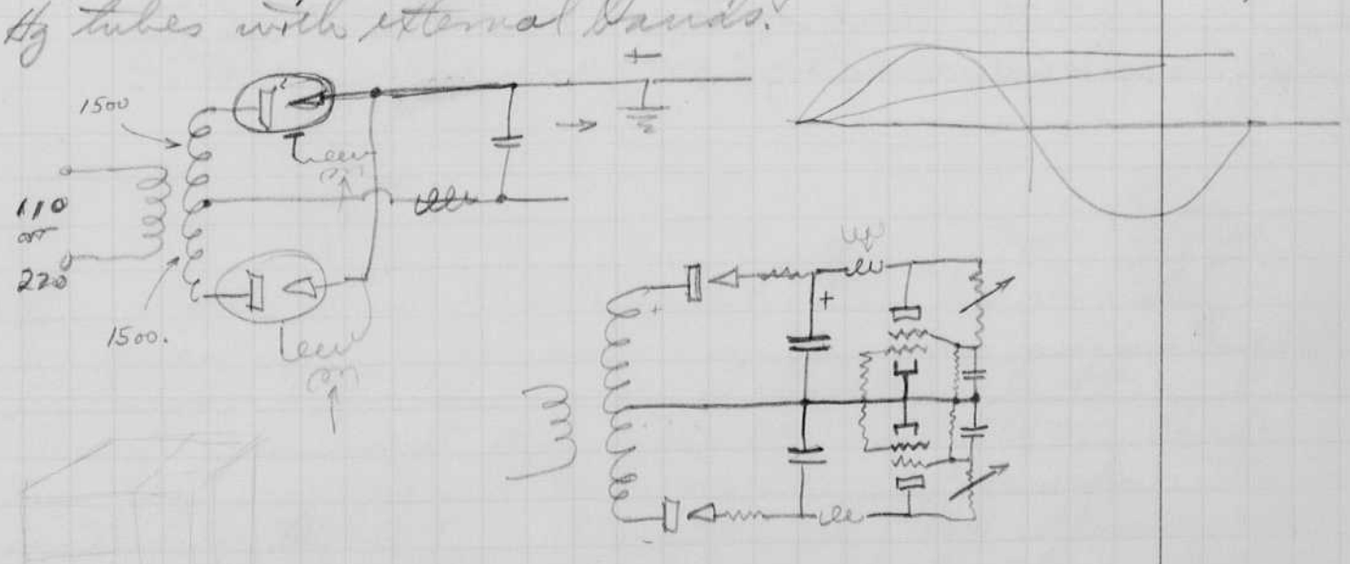
These five pictures were spliced together and a print will be made and sent to Mr Cluett.

I sorted negative in the afternoon, throwing out all old stuff that had been cluttering up our storage facilities.

Dec. 20, 1936. Made prints of various negatives at M.I.T.

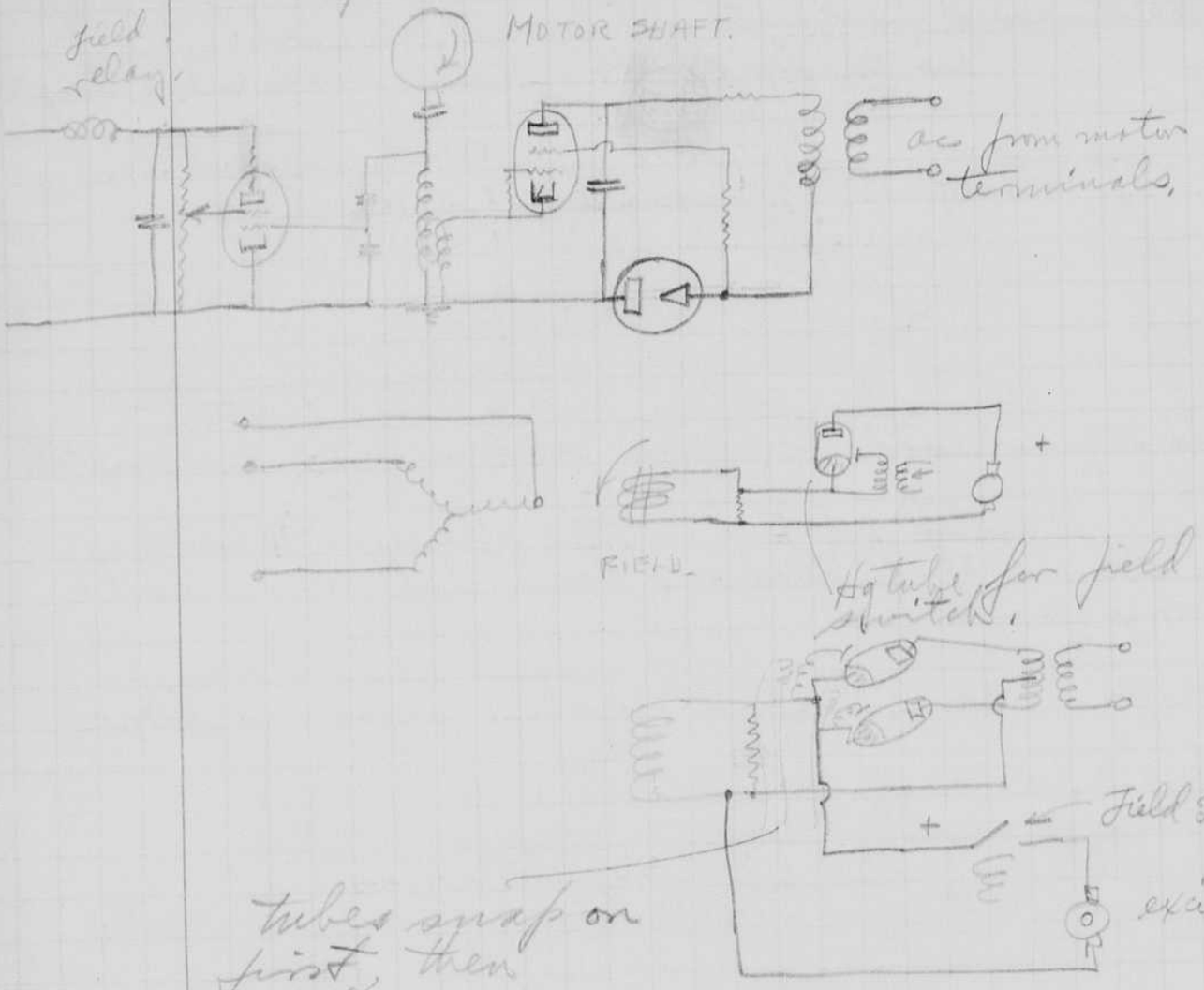
Dec 21, 1936 At Harvard in morning working on 35 movie negative "Seeing the Unseen". Afternoon on odds and ends, and with Nottingham on paper "Starting characteristics of the Double-grid Strobotron".

Constant Power pack for movies using Hg tubes with external bands.



Dec 21 1936
H.S. Edgerton.

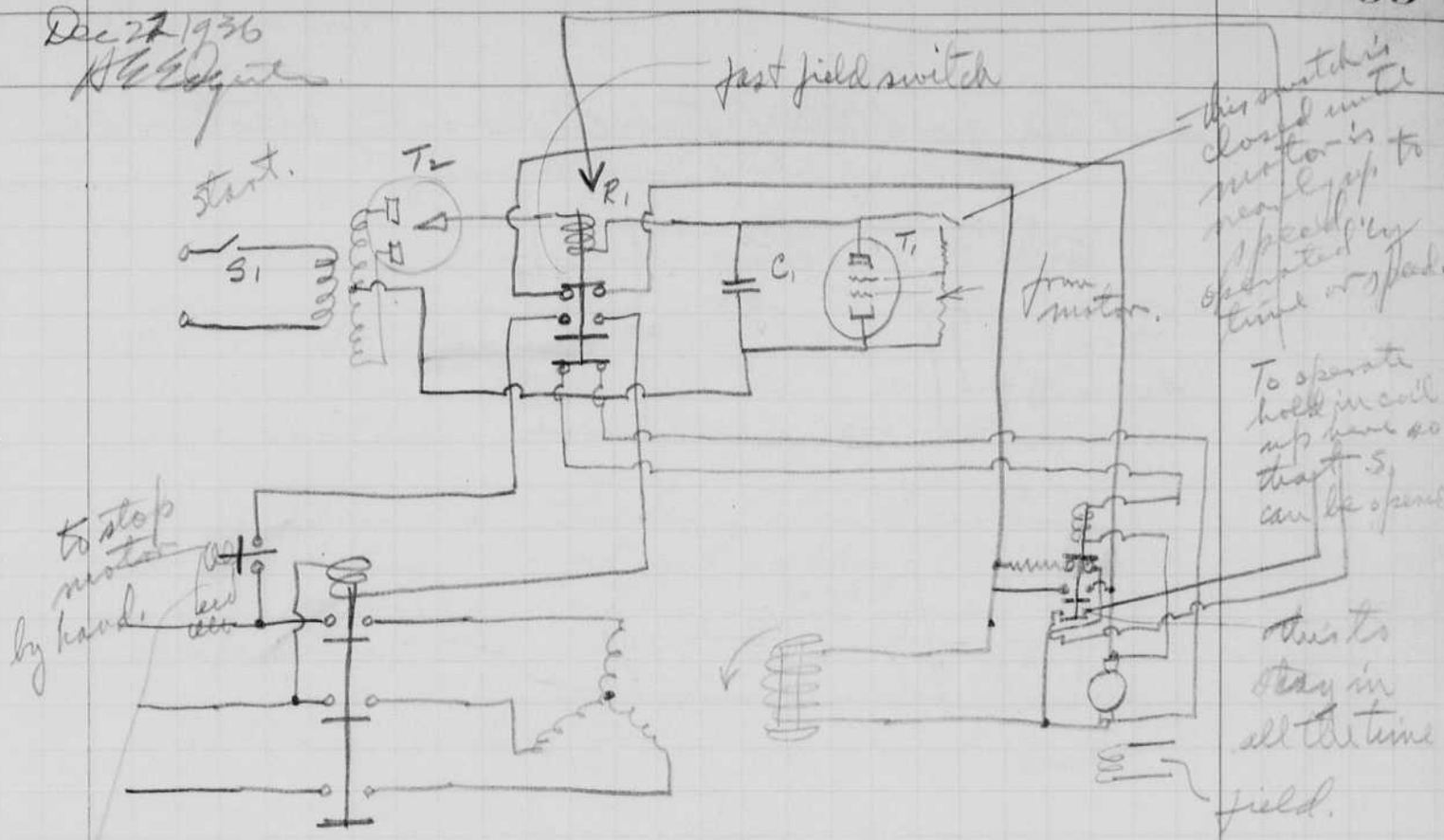
Field Synchronizing



tubes apply on first, then exciter.

Tubes might be used all the time later. Phase control to hold voltage or powerfactor, etc.

Dec 22 1936
H C Stearns

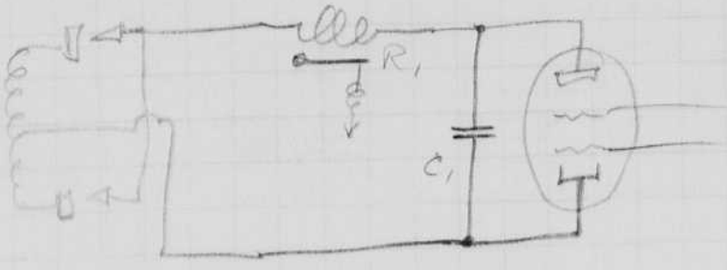


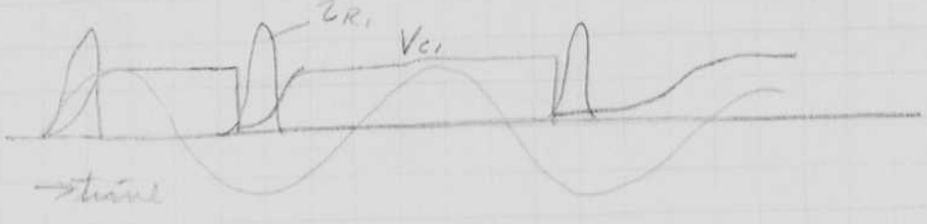
Synchronizing control.

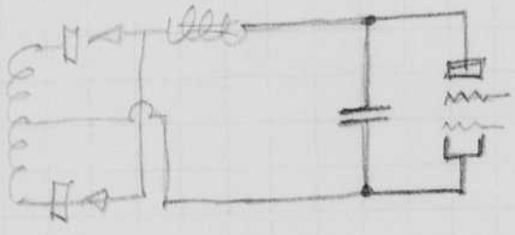
1. Ready to go instantly.
2. No tubes to operate while running (except field excitation in place of exciter by rectifier).
3. No extra brushes on motor shaft.
4. Minimum of apparatus on shaft.

The above strobotron circuit can be made frequency responsive by proper adjustment as follows. The Relay R_1 is held in by the charging current through its coil & the condenser C_1. This current comes in pulses from the rectifier tube T_2. By changing the spring on the relay that pulls it shut it can be made to operate on a miss of 1 or 2 or 3 cycles. The number of cycles missed depend upon the speed of the motor

and the width of the capacity electrode.





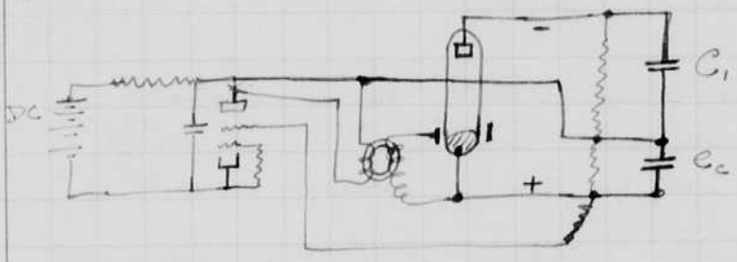


Dec. 22 1936 cont
H.E. Edgerton.

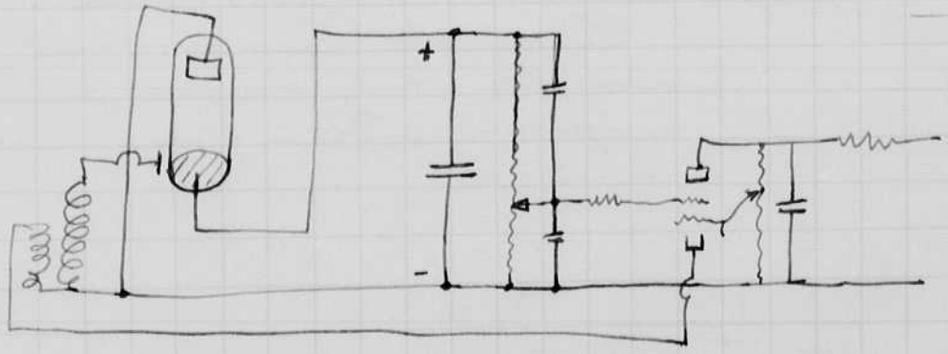
D.C. Power Supply from external Band Hg tubes.

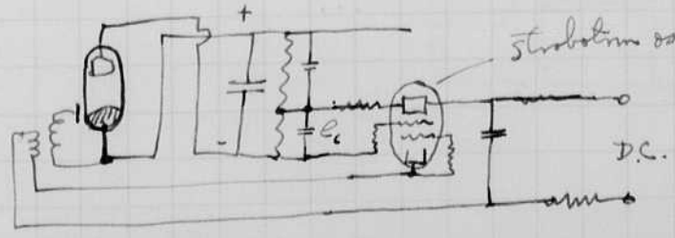
As has been described before, a high negative potential is found to exist upon the anode of a mercury-arc tube with an external band starter, excited with high voltage, (above 2000 or 3500 volts).

I have been thinking about circuits for regulating the output voltage. Such a circuit would be connected so as to keep either current or voltage constant or of a certain determined function of each other.



when as e_c becomes larger the strobotron fires at a slower rate and will finally stop oscillating. The charge going into the condenser C_1 is a function of the number of surges from the oscillator



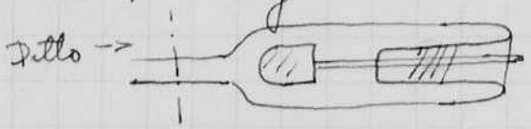


The output voltage e_c controls the oscillation frequency.

Dec 23 1936
H. G. Edgerton.

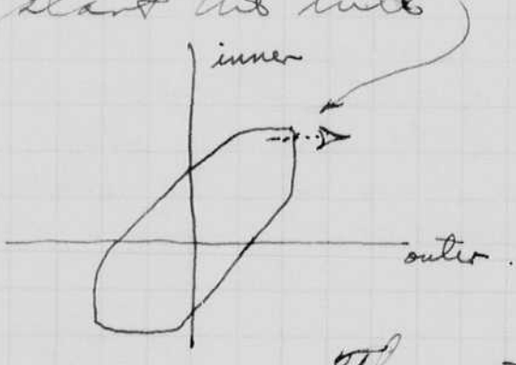
The general scheme outlined on the previous page is to control the number of high voltage pulses from the out put circuit, another method would be to control the magnitude of the high-voltage pulses as a function of the out put voltage or current.

Dec 26, 1936. Pumping Quartz tube. 3mm I.D. 1½" long. The electrodes in this tube are iron (svea.) 3/8" in diam and 3/8" long.



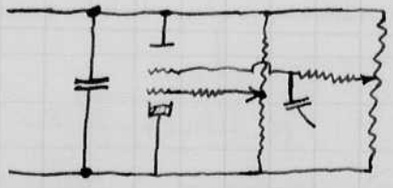
the quartz and electrodes were heated to a red heat while on the pump.

Prof Nottingham and White have found a regim of small grid currents in the discharge that is, less than 10^{-9} amps. is required to start the tube



The grid 1 apparently is prevented from starting by Grid 2 but when G2 does start then the power source to g, furnishes the current.

These old low current regims may be very useful for lots of purposes, such a geiger-mueller counters.



Strobotron Grid Current

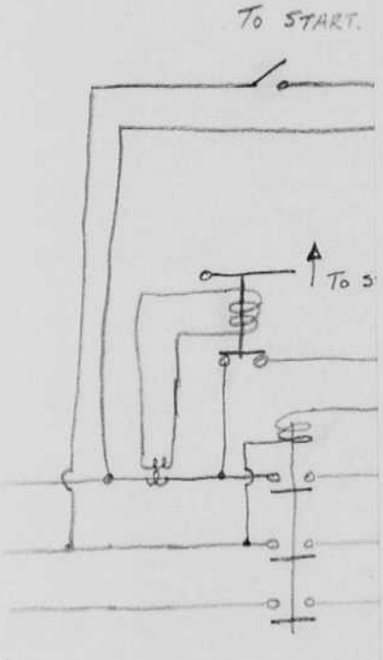
Data as obtained from chart in paper for "Electronics".

measured by
White & Nottingham

I_{G_1}

2×10^{-9} amps.)

I_{G_2}



Drawn Dec 28 1936

1936
gdns.

The general scheme outlined on the
vious page is to control the number of
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cuit. Another method would be to
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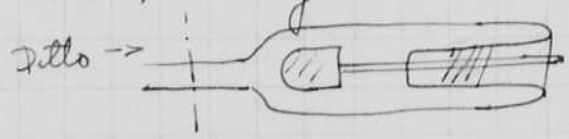
1936. Running Quartz tube. 3mm I.D. 1½" long.
electrodes in this tube are iron (svea)
in diam and 3/8" long.



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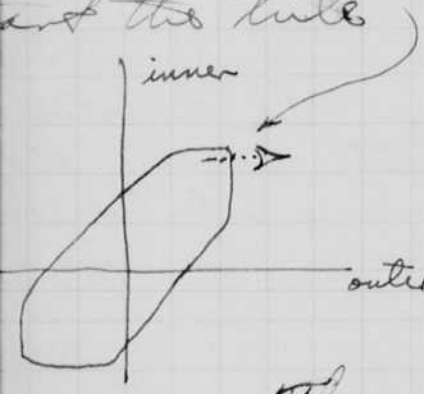

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These old low current regions
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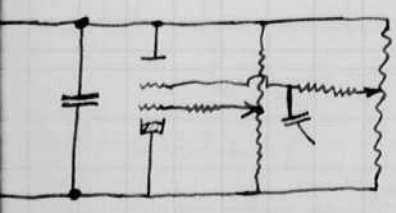
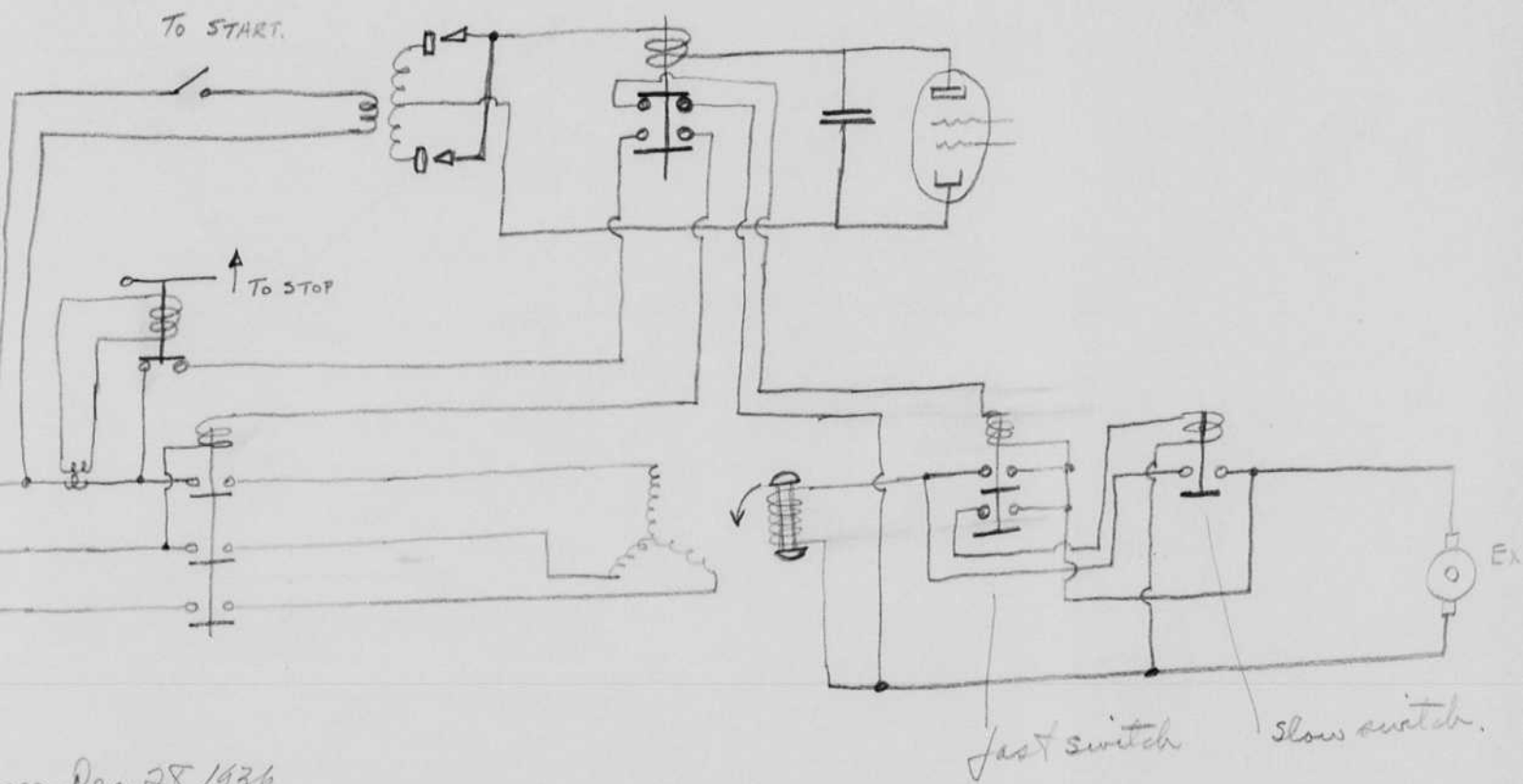


Strobotron Grid Current

Data as obtained from chart in paper for "electronics".

Measured by
Lute & Nottingham

V_{G_1}



Dec 28 1936

1936
gelow.

The general scheme outlined in this
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lses as a function of the output
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1936. Pumping Quartz tube. 3mm I.D. 1½" long.
electrodes in this tube are iron (area)
in diam and 3/8" long.

quartz and electrodes were heated to a
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Prof Nottingham and White have found a
regime of small grid currents in the stabotron
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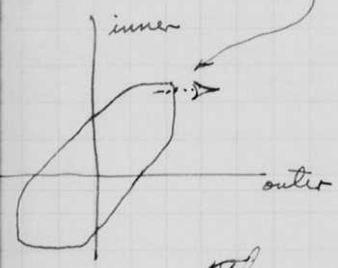

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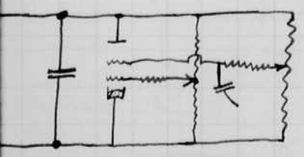


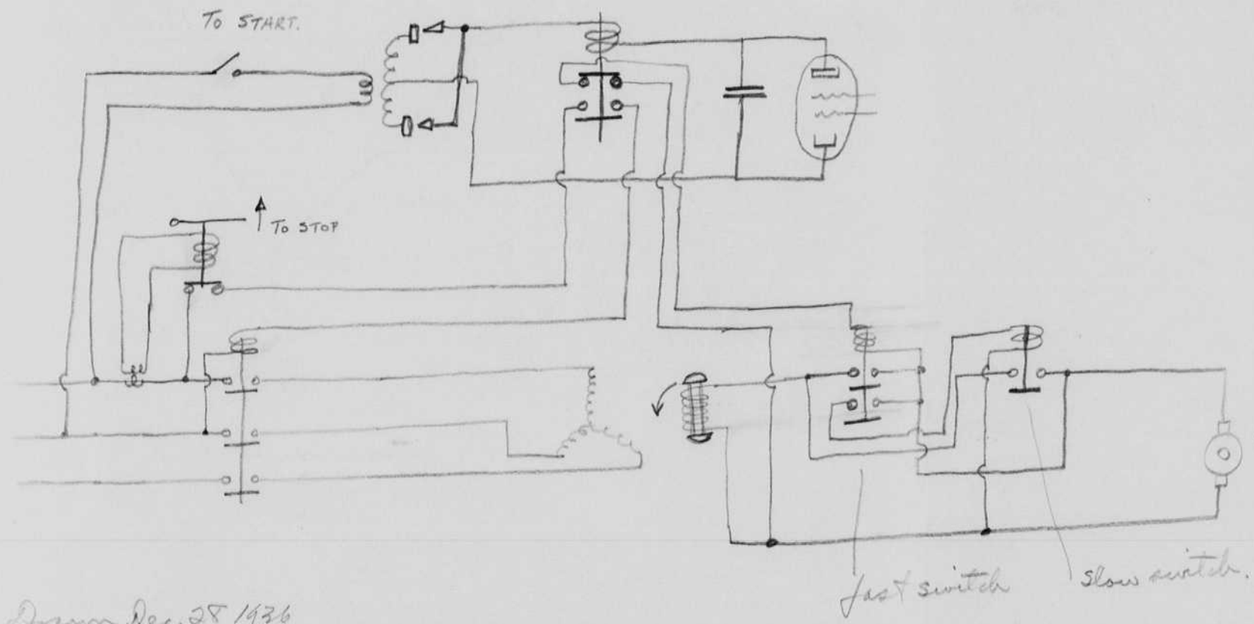
Stabotron Grid Current

97

Data as obtained from
chart in paper for "Electronics".

measured by
White & Nottingham

G1

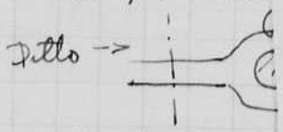


Drawn Dec 28 1936
KHM

Dec 23 1936
H E Edgerton.

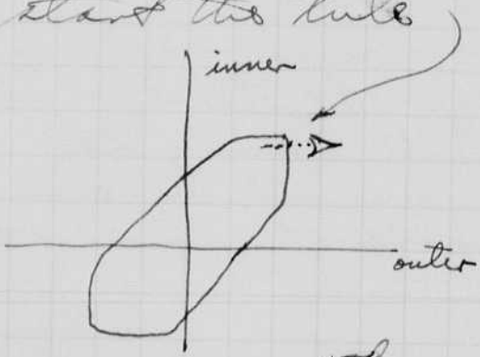
The general scheme outlined in the previous page is to control the number of high voltage pulses from the out put circuit, another method would be to control the magnitude of the high-voltage pulses as a function of the out put voltage or current.

Dec 26, 1936. Pumping Quartz tube. 3mm I.D. 1¼" long. The electrodes for this [illegible] 3/8" in diam and 3/8" long

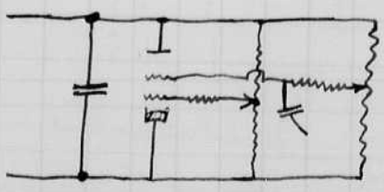


the quartz and electrod[illegible] red heat while on the [illegible]

Prof Nottingham and [illegible] regime of small grid cur[illegible] that is, less than 10^{-9} am[illegible] each of the tube



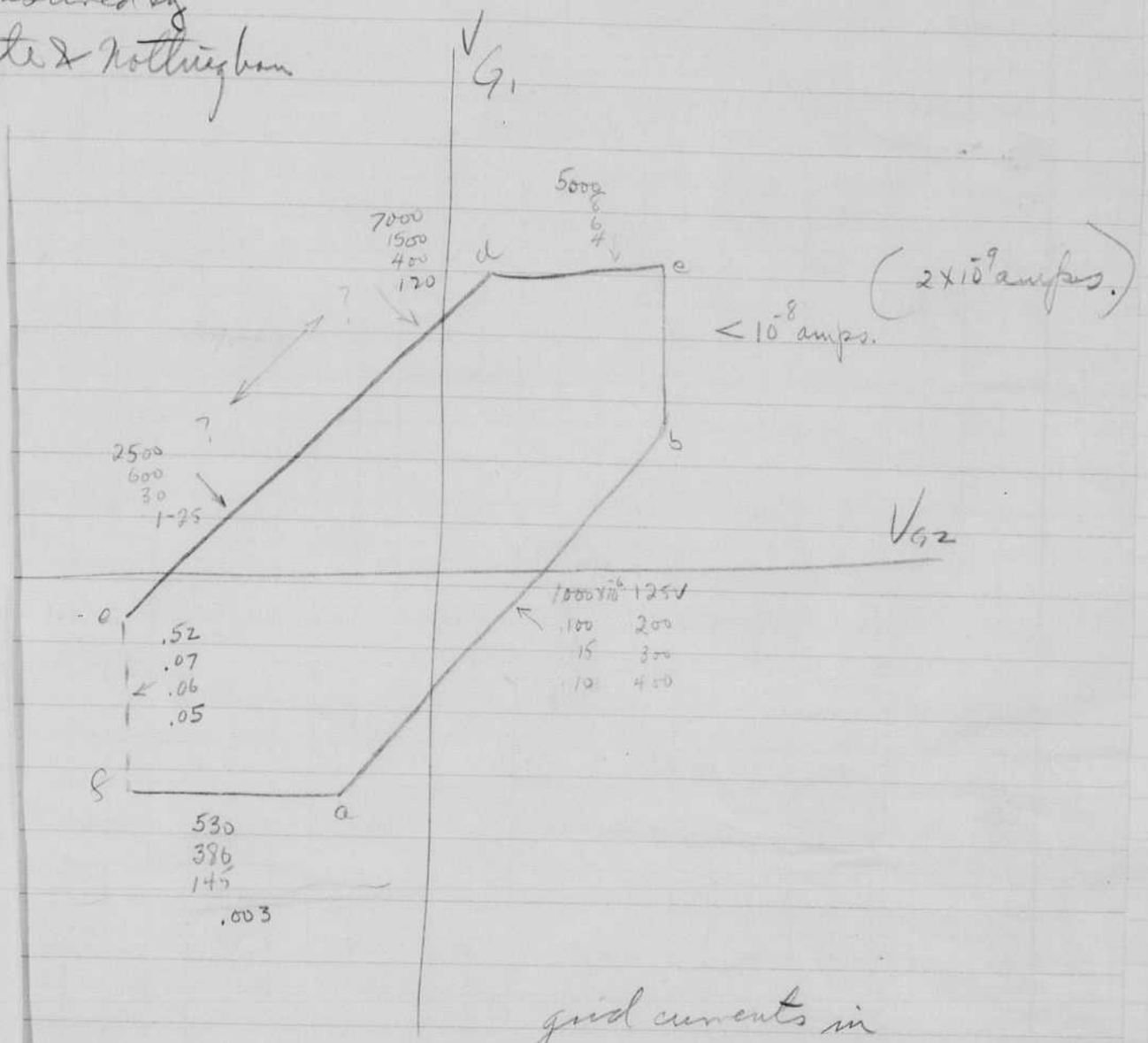
These [illegible] may be very [illegible] purposes, such [illegible] counters.



Strobotron Grid Current

Data as obtained from chart in paper for "electronics"

measured by White & Nottingham



grid currents in microamperes.

Jan 3, 1938
Harold E. Edgerton

I returned yesterday from a trip to Pittsburgh Atlantic City and New Haven. Left at 9 a.m. on Tuesday the 29th arriving at New York at 12. noon. I went immediately to ~~25~~ 250 west 57th. st. to deliver a tripping apparatus to be used with the sheet machine recently sold to E. L. Day. Mr. Day was not there but Mr. Cameron (?) was and I showed it to him. The apperatus worked alright.

Next I went to see Mr Kampfert, who was in Newarke studying the electrical trouble there. Delivered paper to Don Fink at Electronics, and then went up to 54 st to see Mary Ellen and Welch sail away on the Monarch of Bermuda for a 10 day trip. I loaned them my movie camera for the trip.

After show at Radio City I left on the night train for Pittsburgh, arriving there at 8:30. I
Dec 30. looked up Mr. Paul Friedemann of the patent department. We saw E. J. Pollard, Henderson, and C. C. Shutt in the morning before the conference. Those present at conference:

C. H. Marcelon .03 M.I.T. Son took Chemistry
F. H. Sulliksen
C. C. Shutt
P. E. Friedeman patent

I first told them of the application that I have on file using an electrostatic system for angle-switching. Then they showed me the drawings of three applications that they now have on file. These last are by Shutt and Dawson and are along the lines of their A.I.E.E. paper of last year. In some two tubes are used, also contactors on the shaft are used.

Both methods were discussed at length bringing out that the magnetic generation method involved a special unit for each set up - Adjustment of the angle by electrical methods in place of mechanical was mentioned.

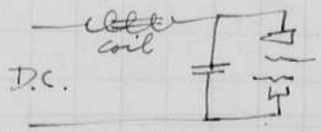
I brought up the question regarding the practical use of ignitrons or other rectifier tubes for supplying the direct current in place of exciters. Mr. Friedmann said that they had ~~an~~ a patent on this feature of 6 or 7 years duration, won by W.E. after an interference with others.

At noon the conf. was adjourned and the group had lunch together with others.

Mr. Helmund chief engineer
J. Slepian
J.A. Cox. (who has been writing to Germeshausen about ignitrons starting using strobotrons).

After lunch Slepian, Cox, and I had a conference about Ignitron starting. I discussed briefly the method and the experiments that Germeshausen and I had been doing. I recommended that it would be advisable for Germeshausen to be assigned to this job for a time in order to make recommendations. They mentioned that it might be possible to do this, obtaining an option to use the methods if they were useful to them. The cost of the investigation would be ~~boo~~ on the Westinghouse Co. At the end Mr. Rose who works with Slepian came in and we discussed the experiments that he and Kilgore did together.

After this conference on Ignitrons, we continued the one on syn. motor schemes. I brought in the use of the strobotron and showed them the circuit



(while charging condenser)

that gives the coil a very hard pull after the strobotron is fired.

I also discussed the use of the double grid strobotron, using one grid with the peaking transformer (or choke) and the other with a surge from the reluctance generator.

Dr. Friedemann took me to the research laboratory and I met Mr. Baker and Mr. Rushing who showed me their balancing machine in operation. Mr. Hanna also was there and he showed me a sound meter that they are using a great deal. I also saw the 16 mm sound projector in Hanna's lab.

Since connections to Pittsburgh are poor Mr. Ireland kindly took me down town in his car.

I took the night train to Atlantic city, Dec. 31. arriving about 10 a.m. The Haddon Hall Hotel had no room for me so I stayed at the Town House Studio at 156 S. No. Carolina Ave. next door to the Hotel. Luncheon at the Hotel with a group of Science teachers, I sat next to Prof Prather of Harvard and Prof Colney (?). and a group of students from Ga. who were attending the convention. I visited the exhibits in the afternoon but they were in the process of being torn down. Saw Mr. Masters (?) Tech graduate of '34 (?) who was working on the R.C.A. demonstration.

There were no meeting in the morning of Jan. 1. At noon I accidently ran into Mr. & Mrs. Laurence J. Webster and had lunch with them. Then we went up to the 13th floor to the meetings in the Rising room. After my movies I rode to N.Y with them and took a train to New Haven. The Garde Hotel near the station was my host that night. In the morning I saw Mr. Pugsley and Mr Robinson about the report on the vibration of a rifle barrel (model 52.) I quoted a price of $250 per gun studied - shape of barrel as a function of time after the gun was fired. Also quoted $300 for a series of shadow photos of the bullet coming from their new swift rifle. 4000 ft/sec. .22 cal

"MIDWAY ON THE BOSTON POST ROAD. THE IDEAL STOPOVER"

1.

Hotel Garde

OPPOSITE UNION STATION

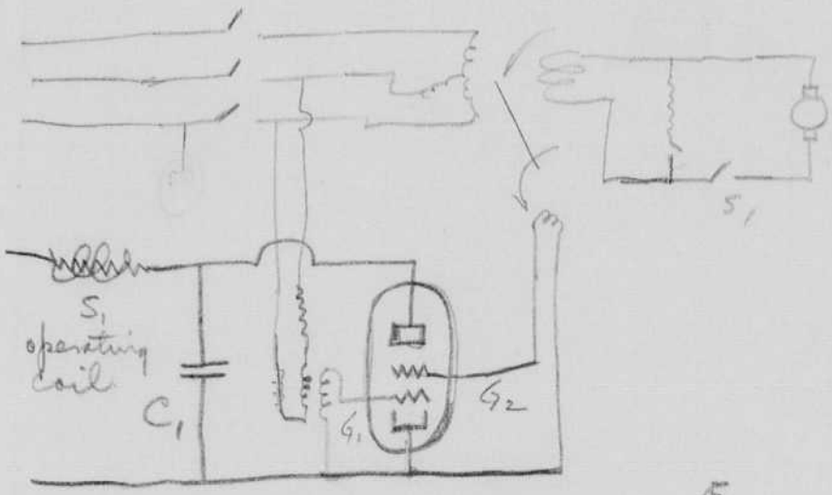
NEW HAVEN, CONN.

WALTER S. GARDE.

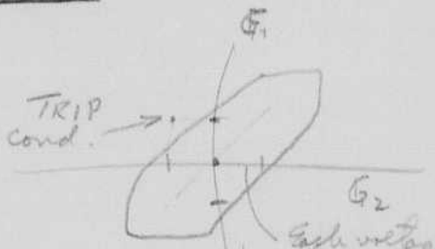
Jan 2 37 N.H.

These pasted in sheets were made on Jan 2 in the Hotel Garde before going to the Windchester plant.

a method of angle-switching is shown which uses the double-grid strobotron as a relay tube.



The starting choke can be used on g1 in place of the peaking transformer shown. See page 85.

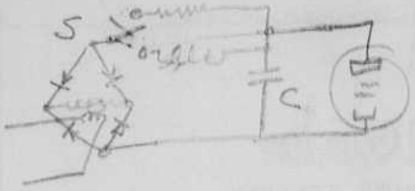


Tube voltage is not enough to trip strobotron by itself but when the plates come together and of opposite polarity they do fire the tube.

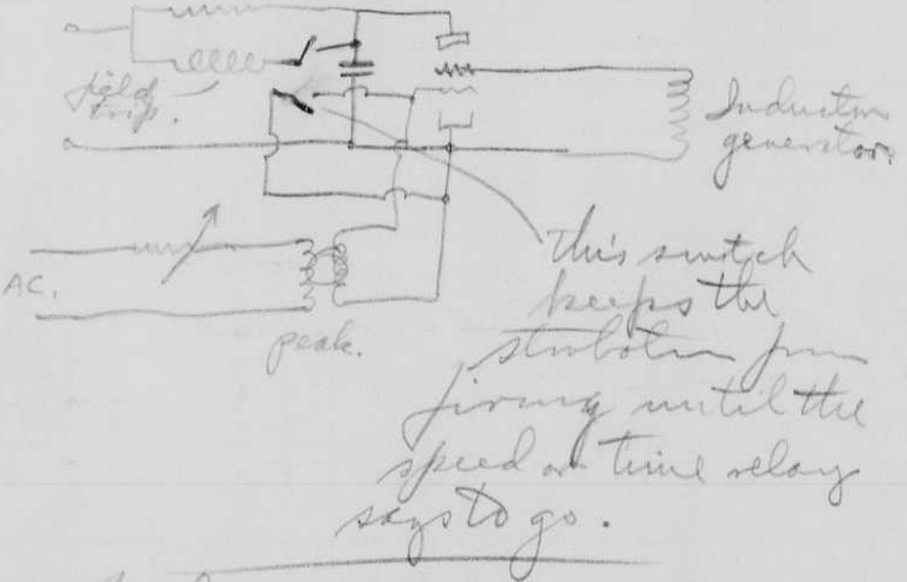
condition for tripping.

C1 must be charged during the starting cycle

2.

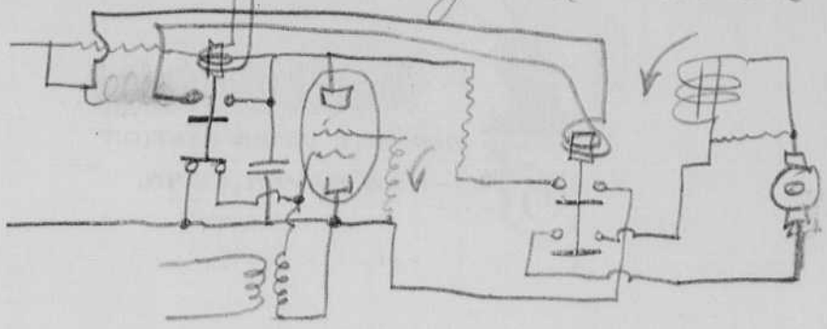


The switch S is put in the upper position during the starting cycle to charge the condenser C. The definite time switch or the speed switch operates the switch S and puts the relay trip spring coil (for field switch) into the circuit.



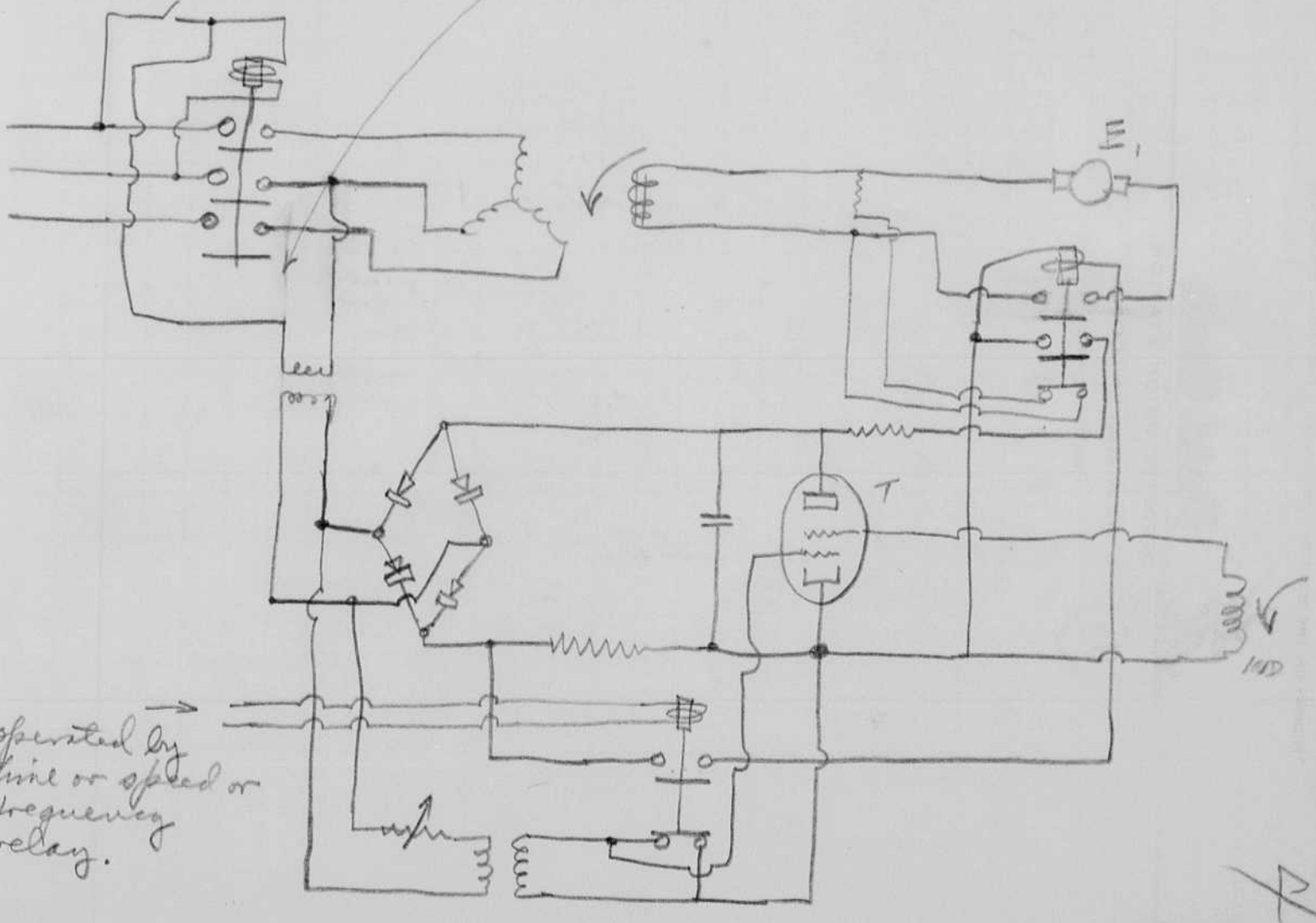
Hold in arrangement.
After the field switch closes there will be a switch on it that will short circuit the stroboton thus allowing a current to flow

that holds in the field switch. 3



Jan 3. This connection changed so that the field switch will be opened when motor is stopped by opening mains switch. Not so good but method is ok.

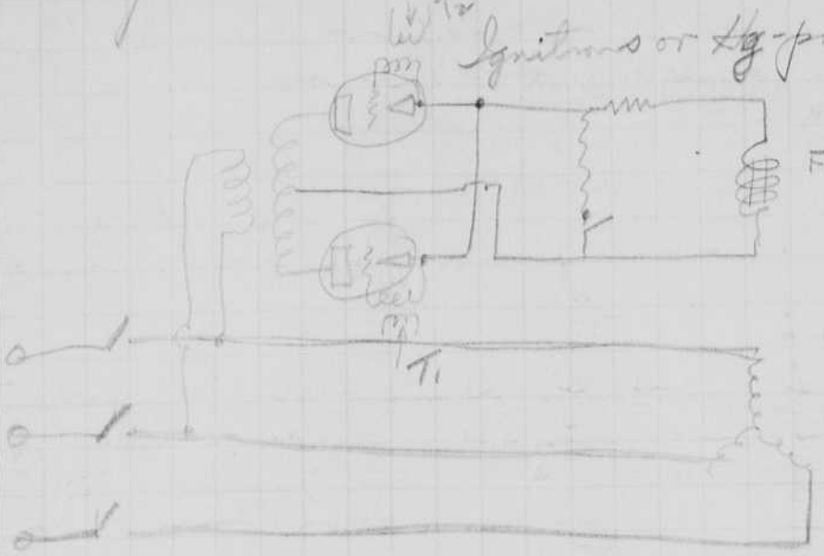
Starting button



operated by time or speed or frequency relay.

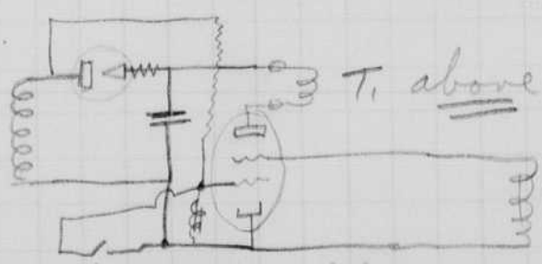
T Strobotron.

Jan 3 '22 Cont.



The desired type of control will be effected by the circuit that feeds power to the Ignitrons or the starting bands Starting Sequence.

1. Armature energized.
2. After definite time or speed of rotor (or slip) the ignitrons or rectifiers are started at the best angle. It should be possible to automatically change the field current after or during the pull-in period. Field discharge resistor open
3. Full voltage is applied to the armature.

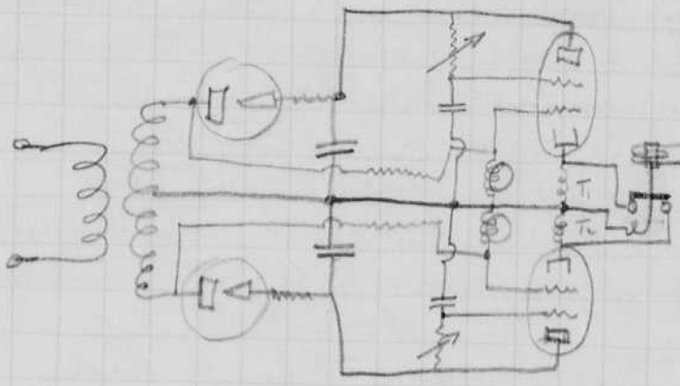


Two circuits like this back to back to drive two large rectifier tubes above

↑ often to condition distributor for angle switching

Ignitron or Hg pool starter

There is no provision for phase control of the starting voltage on the circuit of the bottom of page 105.

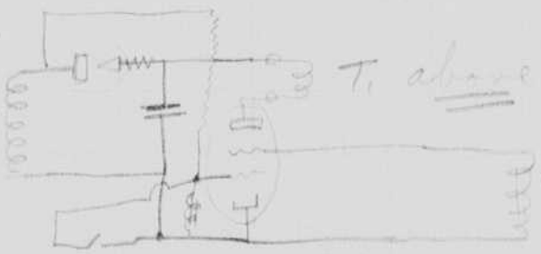


Variable resistors control phase shift

this relay short circuits the input to the spark coils. T_1 T_2

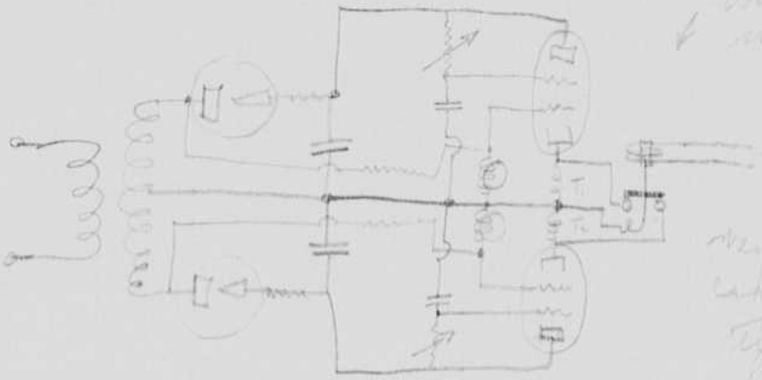
circuit to operate this is "angle" sensitive and may be similar to the circuit shown on page 103 This relay replacing one just below exciter E. The "hold-in" contacts, have been omitted from the diagram here.

Hummingbird.



Ignitron or Hg pool starter

There is no provision for phase control of the starting voltage on the circuit at the bottom of page 105.



This relay shorts circuit to the input to the spark coils. T T₂

circuit to sparkplug thru angle selector and may be similar to the circuit shown on pg 103. The relay repairing on just below starter S, the hold-in contact has been omitted from drawing on here.

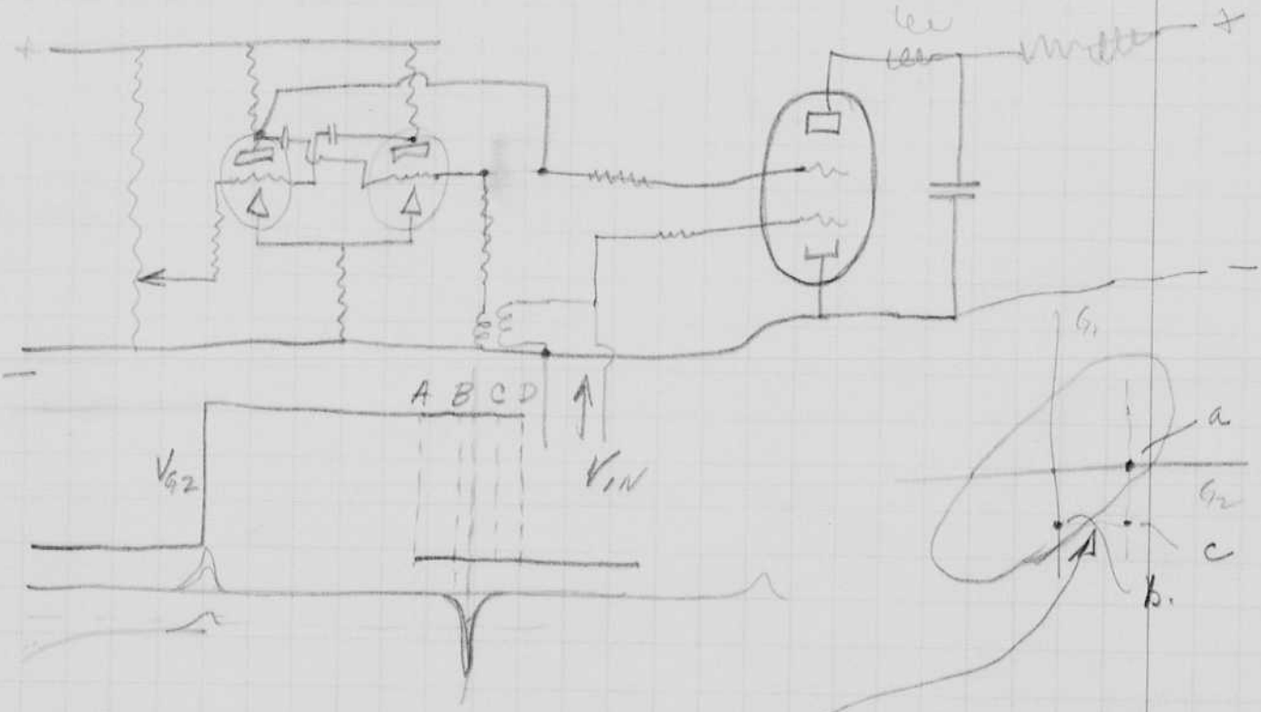
Variable resistors control phase shift

Hummingbird.

Jan 3 '37 cont.

J. E. Edgerton. Frequency relay for throwing in field switching circuit at the desired speed.

It should be possible to do this with a multivibrator type of circuit as a standard for timing. The output (peaked) from a reluctance generator would trip the multivibrator and this would condition a thyratron to fire. After a definite time the thyratron would suddenly take off the voltage. By arranging the amplitudes of the voltages correctly, control can thus be effected which compares the time between pulses for the natural period of the multivibrator osc.

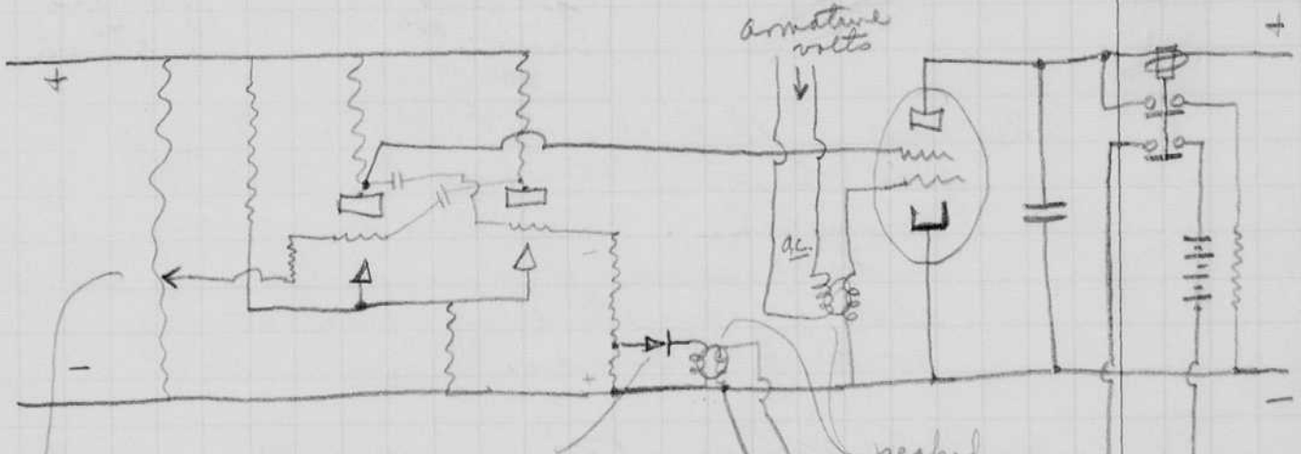


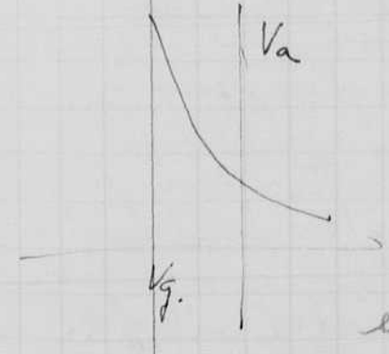
a pulse at V_{in} trips the multivibrator and V_{G2} goes to a positive value (a). After a certain time it will again drops to a low value depending upon the circuit constants and characteristics of the tubes. These tubes may be pentodes where the feedback and

control grid as used ~~a~~ ~~probably~~ instead of in series as shown.

If the voltage at V_{g2} drops off at A then the tube (thyratron) will not fire (see diagram where V_{g_1} is at b on the peak). However the voltage V_{g2} has not dropped such as C and D then the leading peak voltage on grid 1 will trip the tube as at c.

The time between the peaks of the ingoing wave depend upon the speed of the machine.





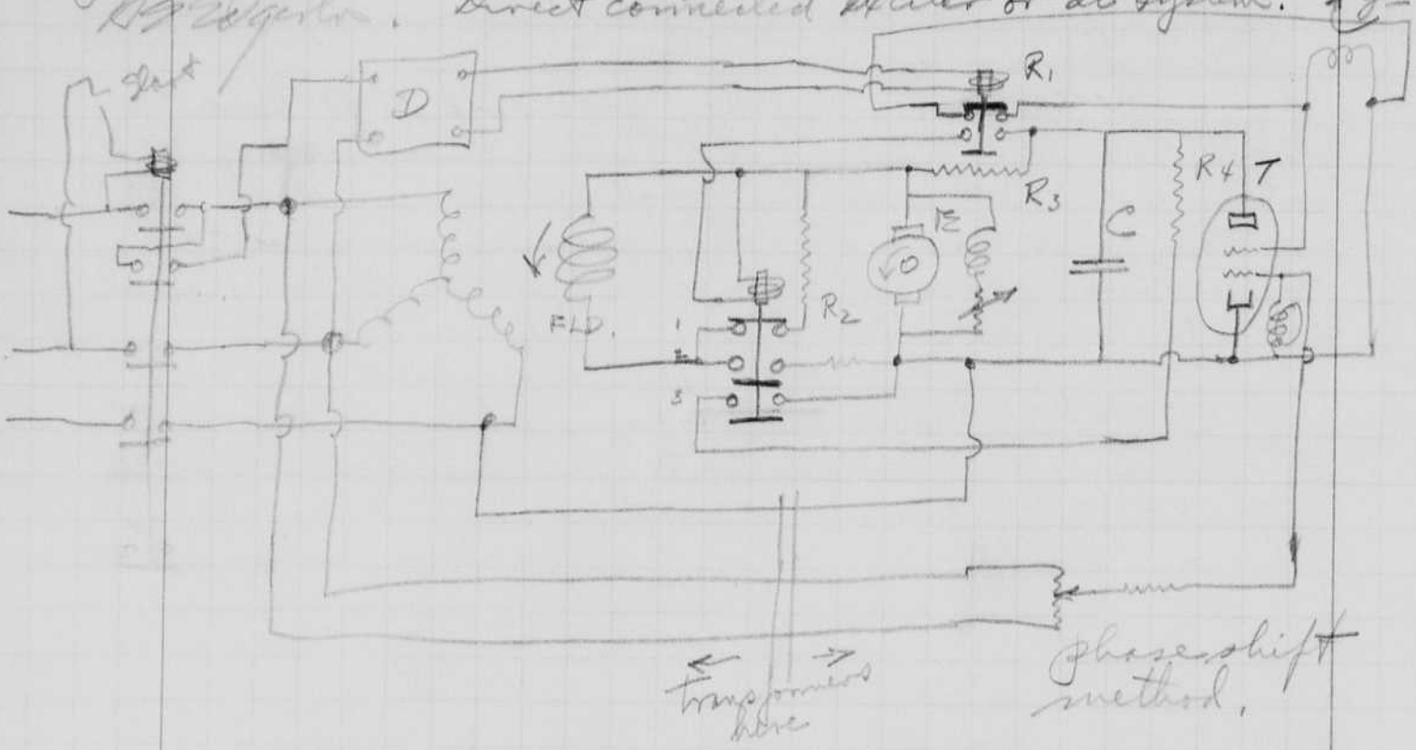
1-3-37

This circuit was explained to me this date by Mr. Bertram

Synchronous.

Jan. 3, 37 cont. Motor Angle-Switching scheme.

Rectifier. Direct connected exciter or dc system. 1 gen.



R_1 Relay that opens short circuit on control grid of strobotron and connects field coil of R_2. R_1 is shown energized by a time delay relay in box D. It can also be operated by hand or by speed or slip devices.

R_2 Field switch. 1. Field discharge circuit
2. Field excitation from exciter E, or dc system.
3. Hold in coil. The tube T does not need to operate after first firing which discharges condenser C. The charging of condenser C from the exciter through the coil of R_2 pulls the field switch closed - Jabt. R_3 is much larger than the resistance of coil of R_2 and is necessary to charge condenser initially. R_4 passes hold in current for R_2 field Sw.

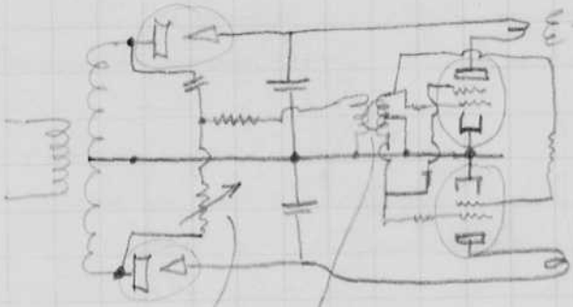
1-3-37

This circuit was explained to me this date
H. E. Bertram

Jan 5 1936
MIT Edgerton.

Pumped argon lamps today and took pictures of milk drops with a student named Kiethley. The tubes were V shaped 12 or 14 mm pyrex with iron electrodes, one was filled with 40 cm argon and the other 20. The 20 works best. At 3000 volts the pressure could be reduced to 2 or 3 cm before the arc self started. Some skips with the 40 cm tube. Arc length about 4 inches.

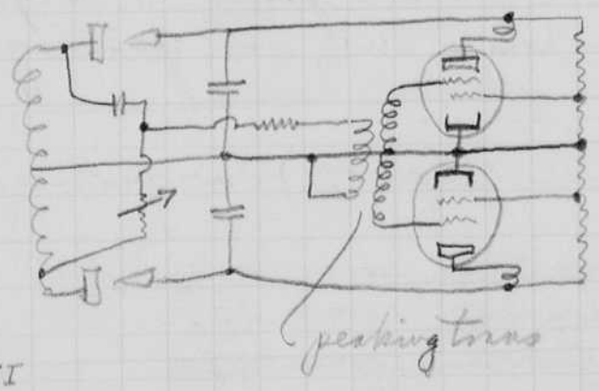
Push pull stroboscope control.



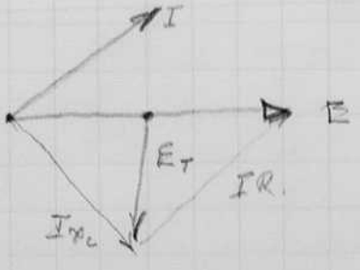
peaked wave form.

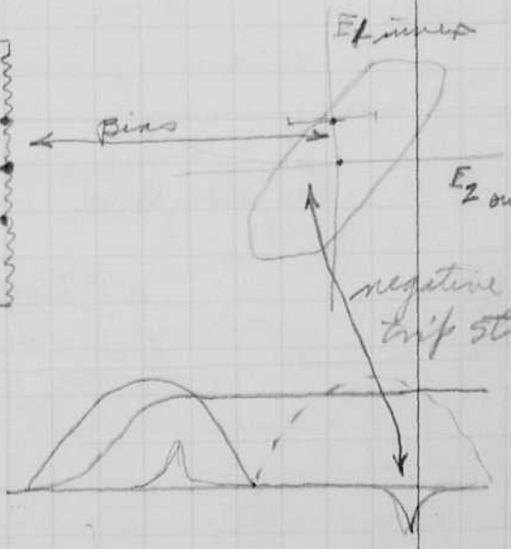
Phase shifting circuit

A possibly better connection is the following.



peaking coils





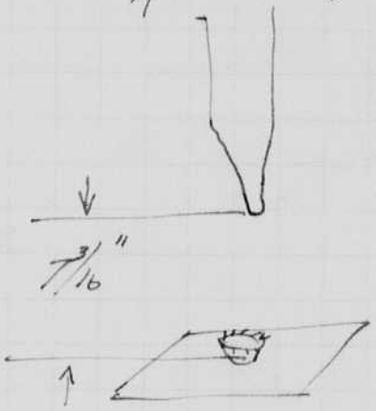
Jan. 8, 1937
H. E. Edgerton.

I have been working with Kiethly for several days photographing milk drops with the time delay circuit. Photos taken yesterday on 5 x 7 with lens at f? 4 mm. enlargement 2 or 3 times.

Today changed lens to give pictures more snap. U.S. 32 .6" lens (from old post card size camera) Safety comm orthochromatic film. Lamp height about 8 or 10 inches from bottom of electric light bulb.

Jan 10. 37 Worked again on photos of splashes.

Two series were taken with the following setup. One set reticulated due to hot wash water. Some of the others were slightly out of focus.



Lens VS 64
24 mf 3000 volts.
Argon lamp 4 or 5" from subject with no reflector.

Jan 11. 37 Printed a series from the negatives taken yesterday. They are quite good.

On the split Dec. 31. (as of) for partnership

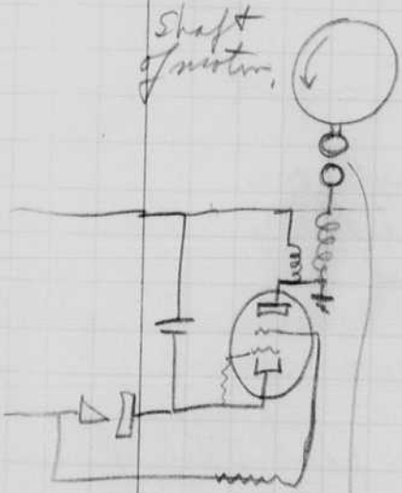
H. E. Edgerton	1000	3050
K. J. Germeshausen	1000	3250
E. E. Grier	1000	2800 ?

Jan 13, 1937
Electra

For several days I have been working up a new synchronous-motor angle-switching ~~scheme~~ application. I plan to photostat the sketches and paste them in this book.

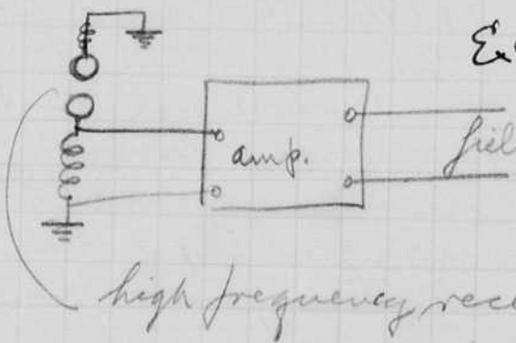
This afternoon I thought of a method of control that might have some merit. If a spark is allowed to flash between two electrodes such as spheres, there is generated very high frequency radio waves. These will be absorbed by a metalic object in a similar manner as light.

Suppose that one of the small spheres was placed on the shaft of the motor and the other in a stationary position below it so that the spark would jump when the two were at their closest point.



Explained and understood
2-24-37 W.B. Tucker

Explained and understood
2-24-37 Herbert E. Grier



high frequency receiver.

Explained & Understood
Feb 19, 1937
Kenneth J. Germershausen

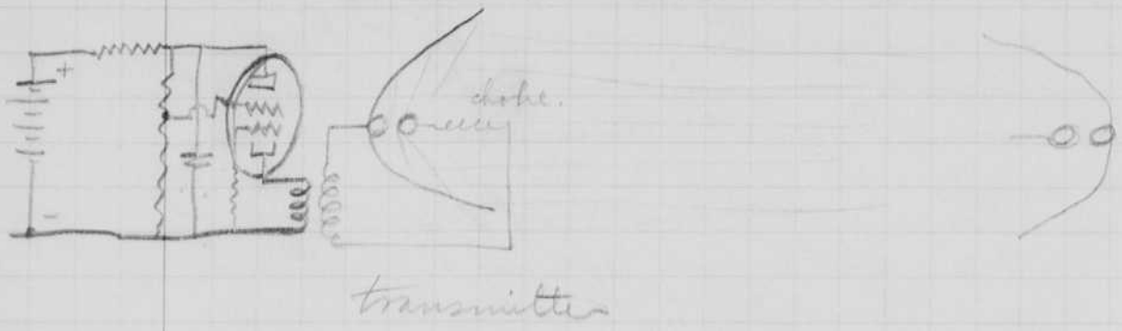
Ultra high frequency transmitter.

This effect has been observed in similar circuits and we know that it will work

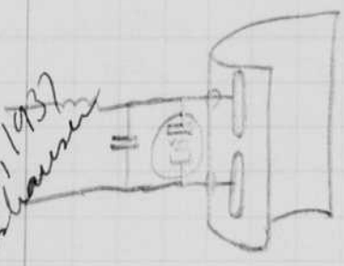
This type of transmitter should be good for communication over short distances, using a reflector type of transmitter and receiver. The only supply of power for the transmitted would need to be the "b" battery. A strobotron would give enough power to

Jan 13 37 cont

make the outfit useful.



transmitter



Explained Feb 19, 1937
Kenneth J. Hemmendinger

For this generator there is no spark. A sudden change of potential across the strobotron starts the oscillations in the tank circuit.

The advantage of the current at the top of the page is that a much higher voltage is obtained from the transformer.

Jan. 21, 1936.

Mr. & Mrs. T. J. Webster Jan 14 for dinner at 205 School St. Belmont.

I talked to the Brookline bird club on Jan 15, at the Brookline library. McLean asked me to do this. Esther ran lantern

Jan. 16, faculty club dance at Walker. Took time photos

Jan 17, Printed time photos and took more. Dead Tyan ran the car.

Jan 19. I talked to the A.I.E.E. in Pittsfield at the Stanley Club horse barn. Spent the afternoon in the plant G.E. Co. While there I saw McEachron, Palmer, Frank Wade Mac Nutt Thomason Christensen (nebraska 27) meader Dowell A Read, Nathan Henderson Le Blanc, Boyajian, Kuge, Allen, Beardsley Brownlee and others. Mark Townsend (Lubbock Texas) went with me on the trip via train.

today I corrected exam papers in the morning. Went over to MacAllister Binghell Glassblowing Co in the afternoon with Mr & Mrs

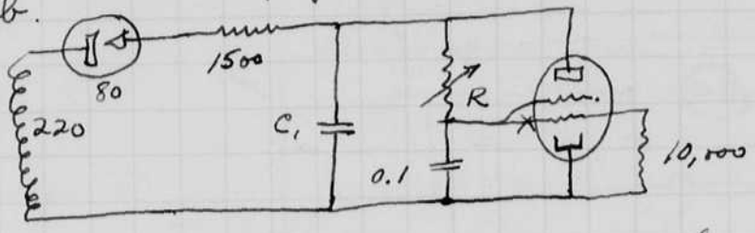
Webster to talk about glass humming bird feeders.
Mr. Mac is going to make a few samples.

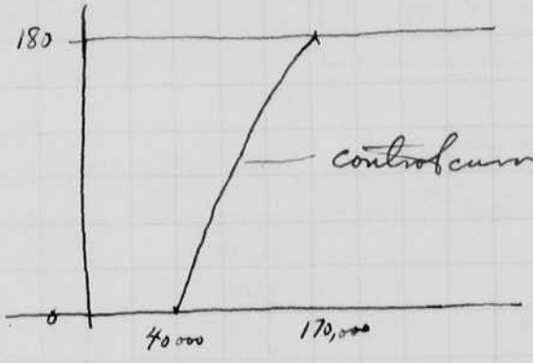
Jan. 26, 1937. Monday.

Worked with Kingsley on discussion of Salient Pole synchronous machine charts by Langsdorf. Chas is going to present the discussion in N.Y.

Two Japs were here today from the G. E. Co.

Phase control of strobotron by RC method. The data below was taken by John C White and Kornblith. in 6.77 lab.



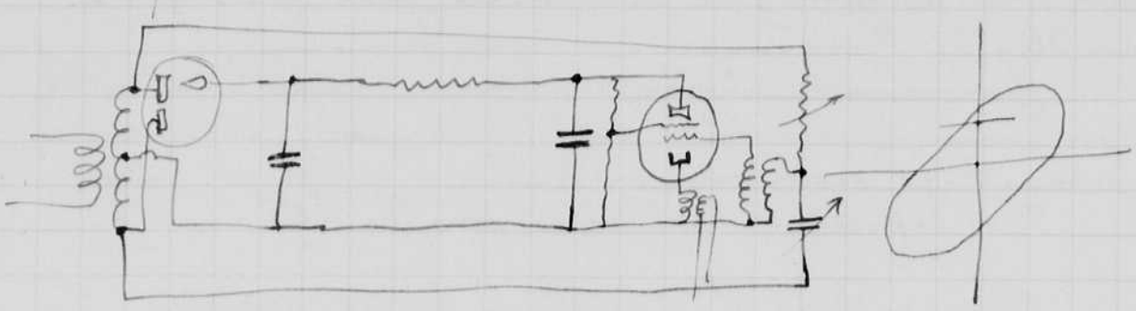


This experiment needs to be repeated with resistance across the coil to prevent oscillations that leave a negative charge on the capacitor C1.

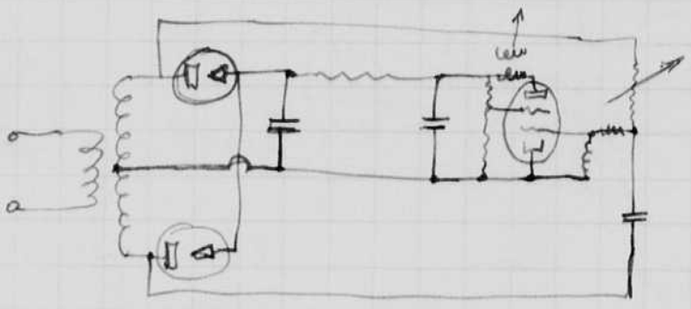
On Jan 24 Saturday I showed the movies to the Audubon Society. Chas. Blake and Mrs. Webster also were there and spoke.

Jan 27 1937
Harold E. Edgerton

Ignitron and Hg pool tube control with Strobotrons.



Phase shifting by the resistor or capacitor.

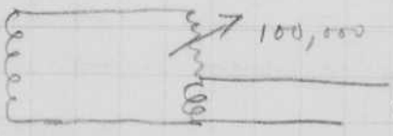


Calibration of G.E. Cathode Ray Osc.

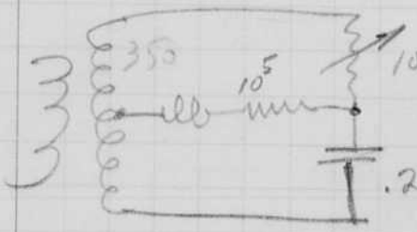
326V

$2\frac{3}{4}$" =	$115 \times 2 \times \sqrt{2}$	2 ma Plate meter
$2\frac{1}{4}$" =		2.5
$3\frac{1}{2} + \frac{1}{16}$		1.5
$3\frac{1}{4}$		1.65

100 volts/inch.



$1\frac{3}{4}$" P-P. 82 volt. ±



works fair.

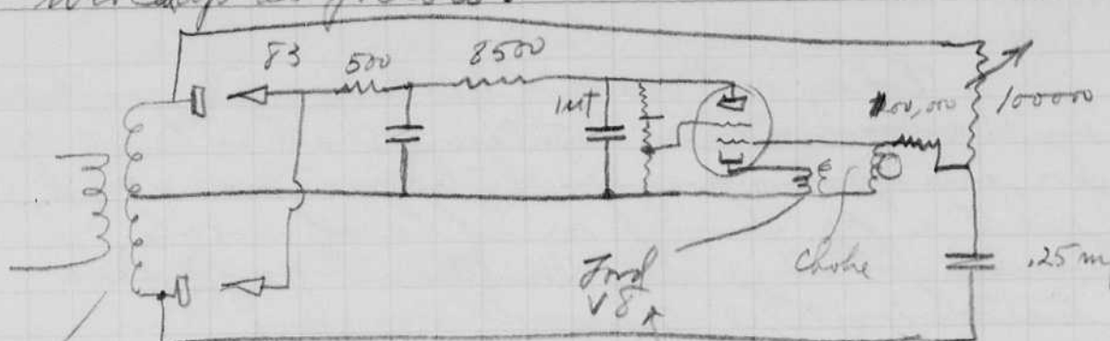
$10{,}000 = \frac{1}{377\,C}$

$C = \frac{1}{377 \cdot 10^4} = \frac{1}{3.7}\,10^{-6} = .26 \times 10^{-6}$

$1 \times 10^{-6} \times 3500 \quad .0035$
$.015$

$RC = .02$
$R = 20000$ ohms.

wired up as follows

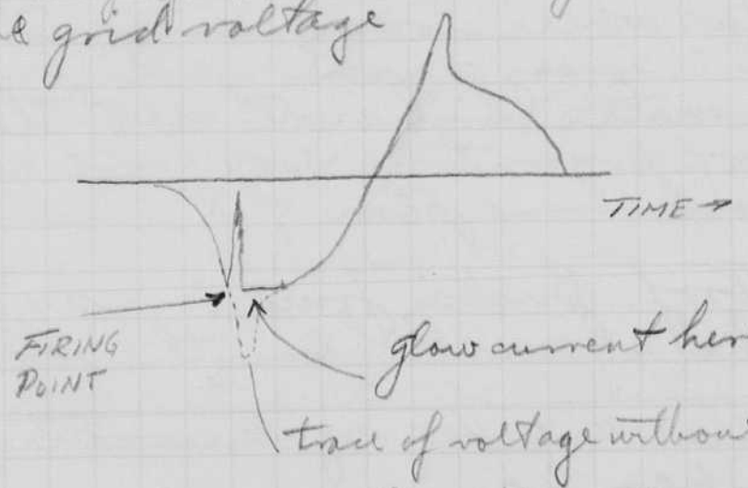


Benatron
T49??
Thordarson.

Works ok with coil shunted.
Holds over in Glow with coil even with 40 ohms in parallel.

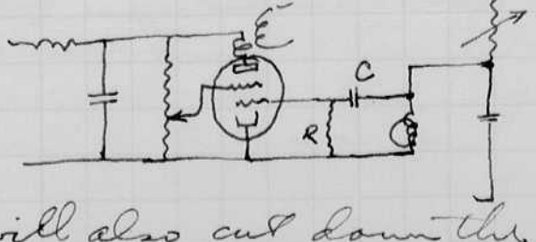
I need to put a small condenser across the peaking choke to hold down the voltage for a short time to prevent hold over caused by glow current.

The oscillograph showed the following curve for the grid voltage



also by the transformer (output) in the plate lead.

Jan 29. 37. Use RC coupling circuit to increase ratio of peak to rest of wave.



Let R = 1 meg ohm.
X_c = 5 megs at 60 cycles.
$5 \times 10^{+6} = \frac{1}{\omega C}$ $C = \frac{10^6}{5 \times 377}$
$= .0005 \times 10^{-6}$ farads.

this will also cut down the glow current.

Jan 28 1937
H.E. Edgerton.

Today and part of yesterday I worked on the vacuum system that is to be used for pumping argon tubes. Townsend put a Hg pump on it last week. I have been filling the McCloud gage and finishing the glassblowing.

There was a metalurgy conference today in Room 10-250. I heard Wulf and Dr A.M. Hall (U.S.E. Co.). More speeches tomorrow.

I mailed today notes of methods of synchronizing synchronous motors with double grid tubes, to mr. Ries. 10 figures were included.

Jan. 29. 1937.
H.E.

Prior and I took photos of Pelton wheel today in the Steam lab. Bob Cheney arranged baffles so that the water did not hit the camera. 12 mf argon tube 3000 volt outfit used. Verichrome film f 8.

Prof. Bucla from ? was here today and I showed him the stroboscope.

also mr. Harry Russel of the Baker Co.

Paul left called on the phone regarding photographs of air waves having a jet. He may come to Boston next Wednesday.

Feb. 3, 1937
H. E. Edgerton

Mr. Paul Moore of North western Uni. School of Speech was here Feb 1 and 2. We took pictures of his vocal cords by both the stroboscopic and the high speed motion picture methods.

Sankey of S E Pittsfield telegraphed that he could not come Wednesday but wished to come after the 12 of Feb.

Feb. 7, 1937

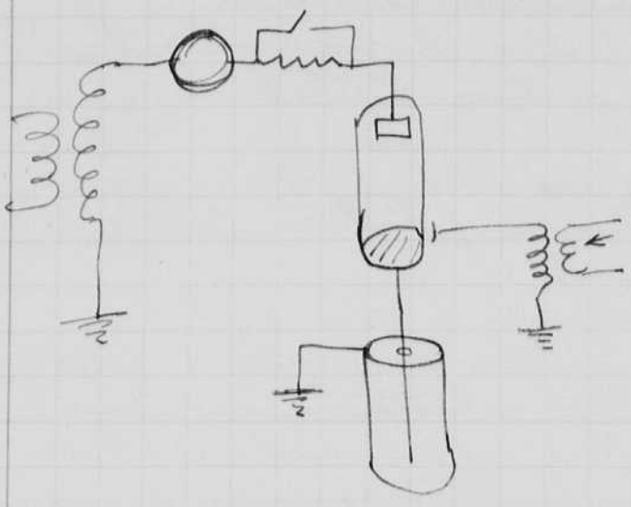
Mr. Rines was at M.I.T. on Saturday Feb 6 and saw Prof. Cady in my office. I showed him (Rines) records regarding early stroboscopic experiments in particular a demonstration on open house april 1928 in the research laboratory. M. F. Gardner who was my boss remembers the set up and the exhibit. Mr. Kershaw, mechanic remembers the device he made for the exhibit. T. S. Day could not remember the apparatus.

Mark Townsend was back on the 6th from his trip to G. E. Vapor Lamp co and Schudy G.E.Co. He said he had a fine day at Holoken at the lamp co and that he told them of his experiments with the current from Hg tubes having external bands.

Feb. 10, 1937. Second term started on Feb. 8. I have a section of 6.02, 14 students, the "C" section. Hoyer has the "A" and Timoshenko the "B". Cahoon is reading problems.

Alexander from the Simplex Wire & Cable came in this afternoon and requested data on large thyratrons for testing cables. I told him about the Hg pool tube and the strobolite started. Grier and I showed him the ignition starter circuit in operation.

– cont Cable tester for burning out the short circuits in a cable.



Strobotron or thyratron trip apparatus.

Phase control for adjusting the current.

Feb. 11, 1937 Pasadena.

Semmelhausen went out to Raytheon yesterday and got some small stems. Percy Spencer told him about a oscillograph using an ink gun and electro static deflecting plates.

Willis of the Sperry Gyroscope co. was here ~~yesterday~~ today with Draper and we discussed the photography of ball bearings. They are interested in a camera or consulting work here.

I showed the 602 class the ignitron starter that Semmelhausen wired up last week. It seemed to run fine, that is without any missed in the ignitron.

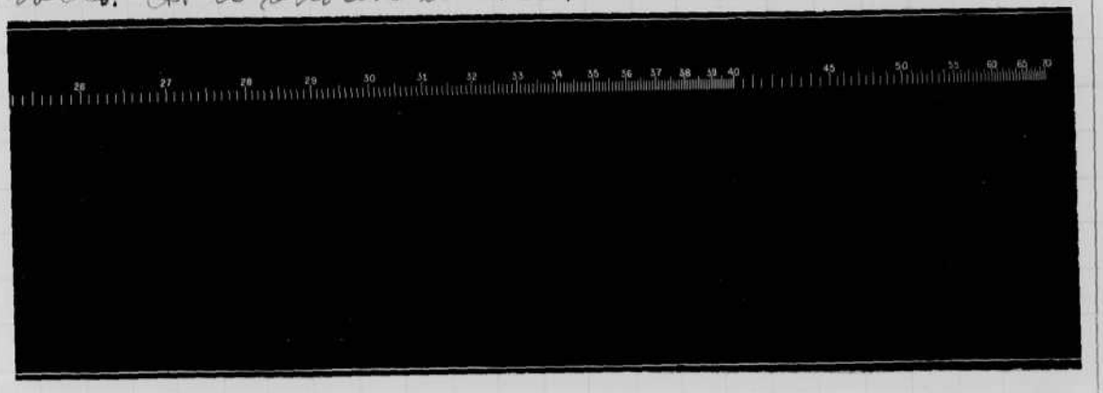
Bill Tucker has been helping me design an argon spark machine the last few days. I got an old box and some of the parts together last night. It will be something like the apparatus on page 75.

Feb 14 37. Von Tipple brought Prof Boer and his son Hans into the lab on Saturday and I showed them the last reel of movies. Bennet also was there. I took a photograph of them with the engine

lamp. f 4.5 and f 8. 24 mf 300 volts. 7 ft from camera and light to subject.

Feb. 16, 1937. H. Edgerton.

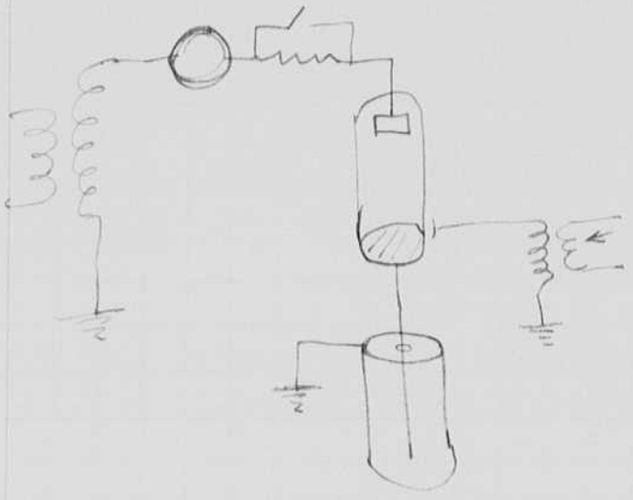
Tucker took a spectrogram of the argon lamps 12 mf (also 24) 300 volts. It is shown below.



The yellow and orange are missing. I am going to build a tube with Mg electrodes and I believe that a small amount of the material will be vaporized in light to produce some gas in time for the discharge. If the tube sputters it can be heated to drive the Mg from the walls to the end of the tube.

Merrill of the Physics dept. talked to me this a.m. about the use of the argon lamps in an enlarger. I am using a point source of light and no lens. This would work if a point source of light could be obtained.

cont Cable tester for burning out the short circuits in a cable.



Strobotron or thyratron trip apparatus.

Fine control for adjusting the current.

Dec. 11, 1937 Bridgeport.

Bennet Hansen went out to Brighton yesterday and got some small stone. He explained to him about taking a photograph using an ink gun and electrostatic deflecting plates.

Willis of the Sperry Gyroscope Co. was here ~~yesterday~~ today with Draper and we discussed the photographing of ball bearings. They are interested in a camera or something for doing work here.

I showed the 60 cycle ignition tester that Bennet Hansen wound up last week. It seems to run fine, that is without any missed in the ignition.

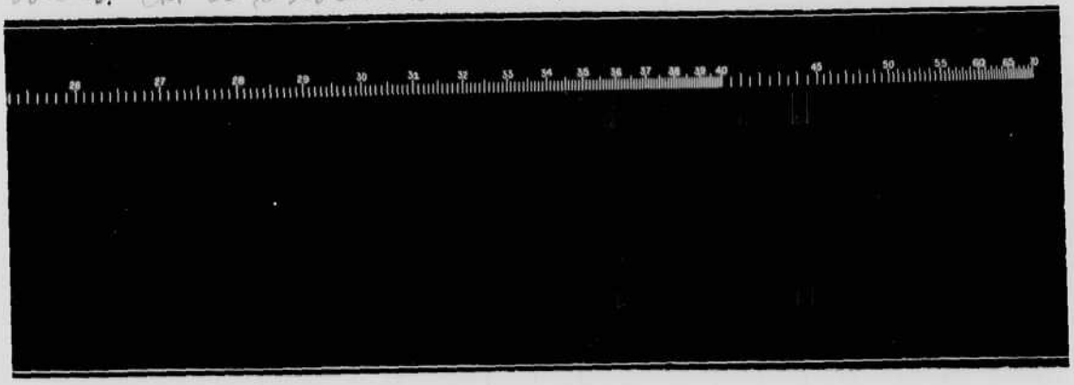
Bill Fraser has been helping me design an argon spark machine the last few days. I got an old box and some of the parts together last night. It will be something like the apparatus on page 75.

Feb 14 38. Von Tippelskirch brought Prof Boer and his son Hans into the lab on Saturday and I showed them the last reel of movies. Bennet also was there. I took a photographic of them with the argon

lamps. f 4.5 and f 8. 24 mf 300 volts. 7 ft from camera and light to subject.

Feb. 16, 1937. Hodgson.

Tucher took a spectrogram of the argon lamps 12 mf 2 to 20) 300 volts. It is shown below.



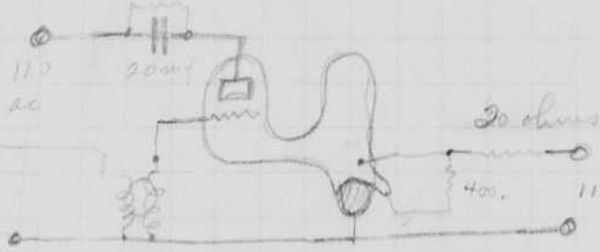
The yellow and orange are missing. I am going to build a tube with Mg electrodes and I think that a small amount of this material will be vaporized in light to produce some gas in time for the discharge. If this tube sputters it can be heated to drive the Mg. from the walls to the end of the tube.

Merrill of the Physics dept. talked to me this a.m. about the use of the argon lamps in an emergency. I suggested using a point source of light and no lens. This would work if a point source of light could be obtained.

July 23 1927
Mr. Edgerton

Yesterday Dick Cutts and Kenneth Beardsley were here and discussed early stroboscope experiments with Mr. Rines. Their testimony may be used in a patent interference with R. Troulsen regarding a fundamental patent claim.

I plan to hook up the earliest model if I can find the tubes etc.



$RC = .01$

$R = \frac{.01 \cdot 10^6}{20} = \frac{10^3}{2} = 500$ ohms.

The above experiment was started today. Cutts and Rines want to look at it on Friday morning

Mr. Ryder who works in Fitzpatrick's office told me over the phone today that the tube #448141 was made on March 17 1927 and is rated 20 amps 200 volts.

Brown gave me the bulletin on the new Magnetic Stroboscope that came from the General Electric in Jan. 1928.

I sent this with Cutts and Beardsleys thesis to Mr. Rines. Also tube # 448141 which had no mercury in it.

I saw Barrow in the hall today and told him that I was planning to see him within a week or so about the short wave radio method of synchronizing a synchronous motor at the least angle.

this method was explained to him in Walton's on Jan 13 or 14 while eating.

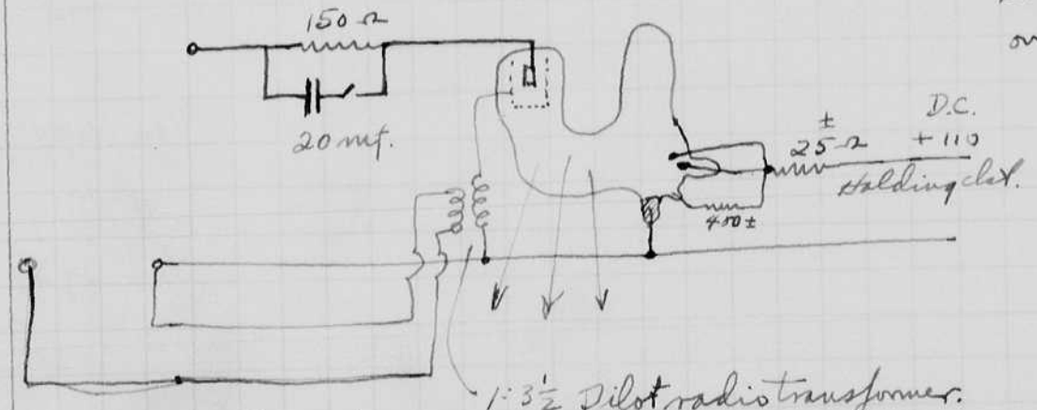
Mr. Alger phoned from Schenectady on Friday Feb. 19 about 9 30 am about the synchronous motor synchronizing schemes. I told him about the trip to Westinghouse during the vacations.

Esther and I left about 11 am. for Proctor (Friday 19th). Vt. to talk to the University club there. We were the guests of Mr. & Mrs. Redfield Proctor. On the 20th we went to Middlebury and saw the Nottingham's and White, also his parents. The Ski jumping at the college affair was quite exciting. Returned to Belmont that afternoon.

Feb. 24, 1931.

I wired up the circuit on p 120 which was started yesterday

this circuit was shown in operation to Mr. Rines and to Mr Cutts on or about Feb 26 31



Works ok

~~Schol~~ Shoults called on the phone this aft. from Schenectady (G.E.) and mentioned coming over to see about sync. motor schemes this weekend. He may come sunday.

a bat supplied by Mr. Griffin of ~~Harvard~~. Lowell house

Hans Bohr.

Dr. Bohr.

Von Hippel

at M.I.T.

Feb 1937.

Humming birds.

Paul Moore getting his tonsils sunburned! while taking movies of his vocal cords. Folds

From North Western Univ. Chicago

Harry L. Day

New. York City.
E.R.P.I. Co.

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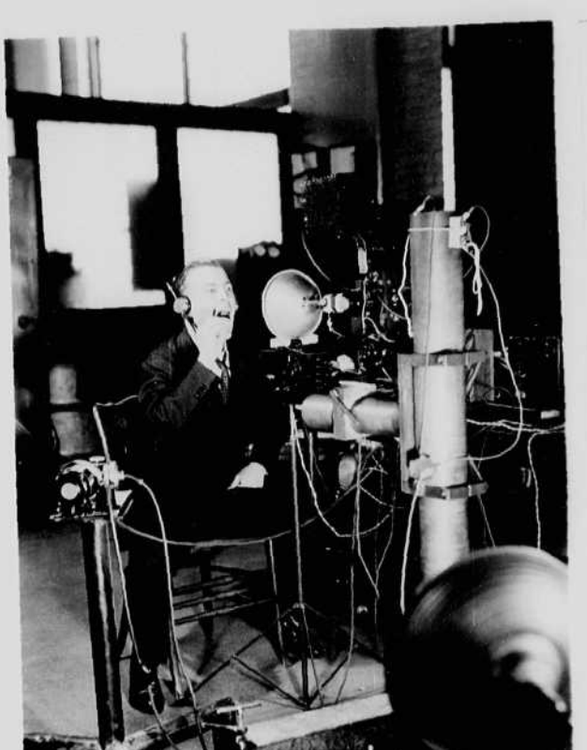

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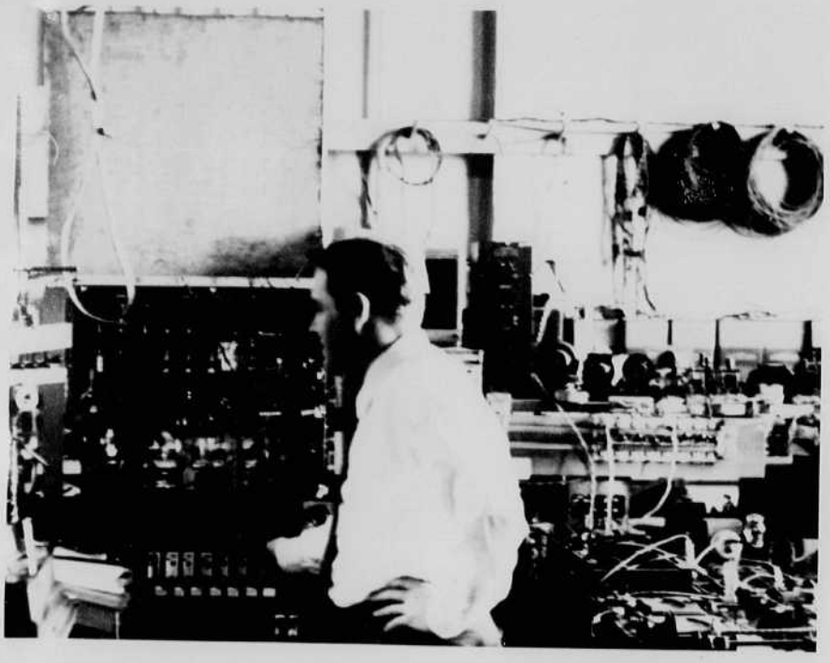
New York City.
E.R.P.I. Co.



Wayne B Nottingham in his laboratory Building 8.

Taken Feb, 24. 1937.

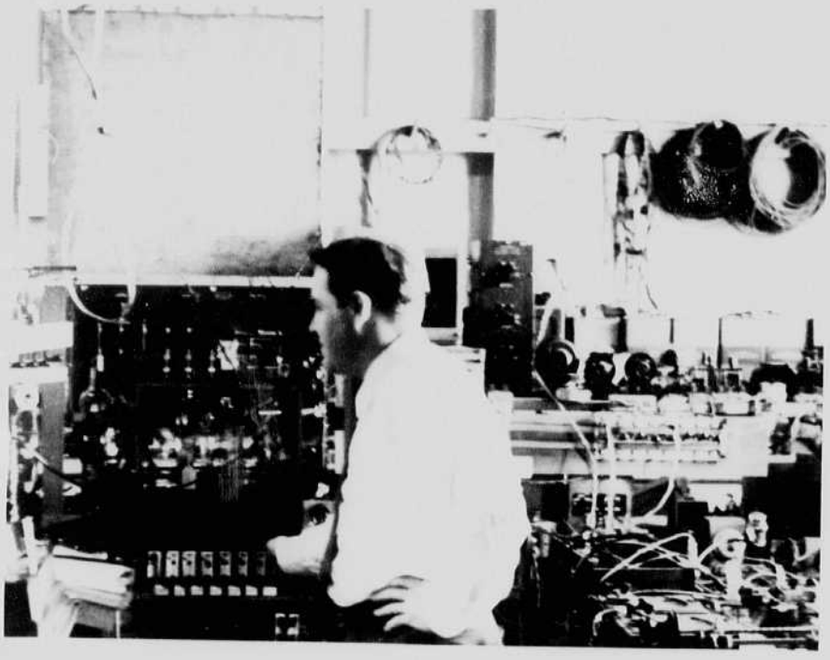
Bill Tucker. Research asst.

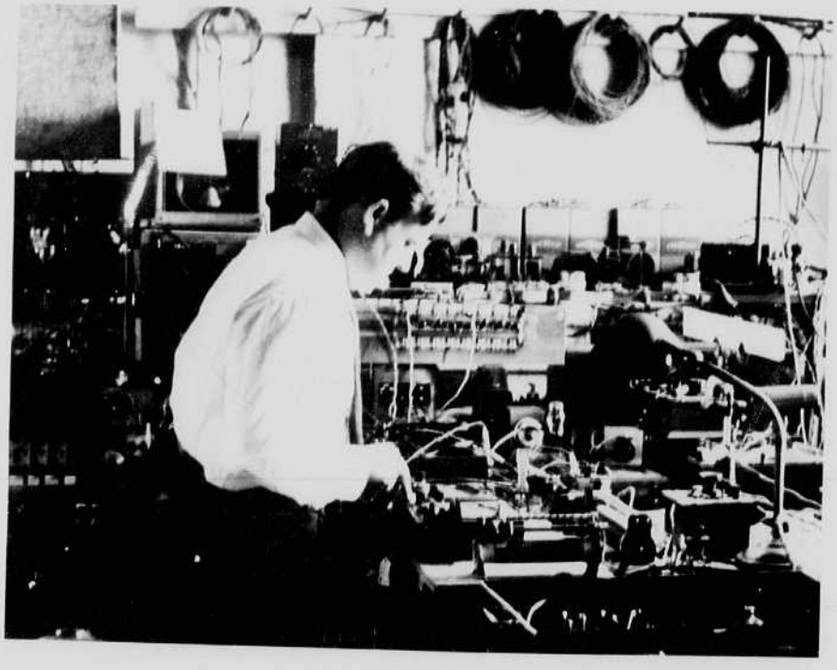
Yours truly.

all taken at f12 with Leica 2" lens.

Mark Townsend.

the above were taken with the light from two argon lamps. The blue brings out the freckles and does not give a pleasing picture as could be desired.





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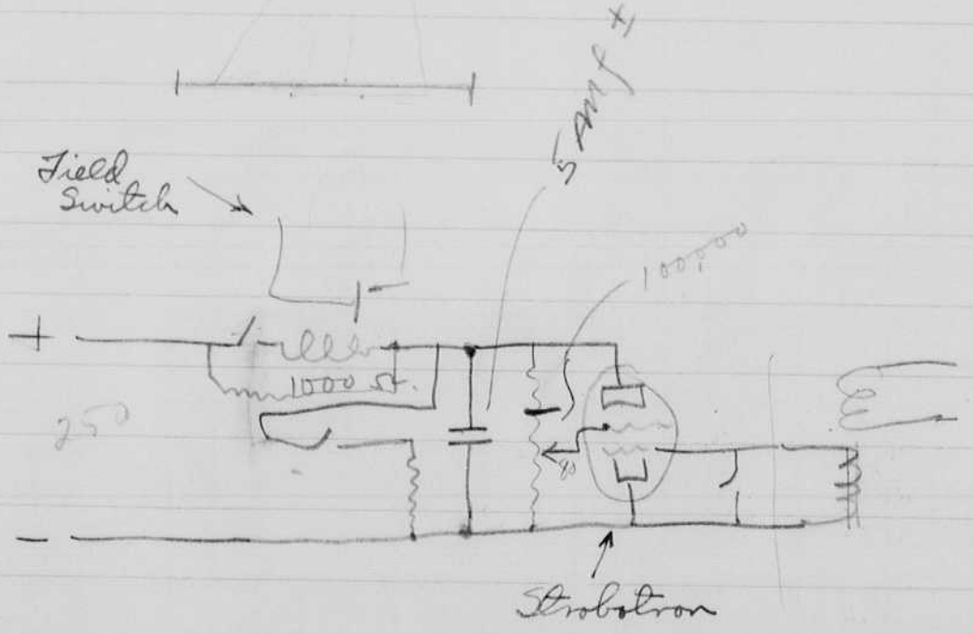
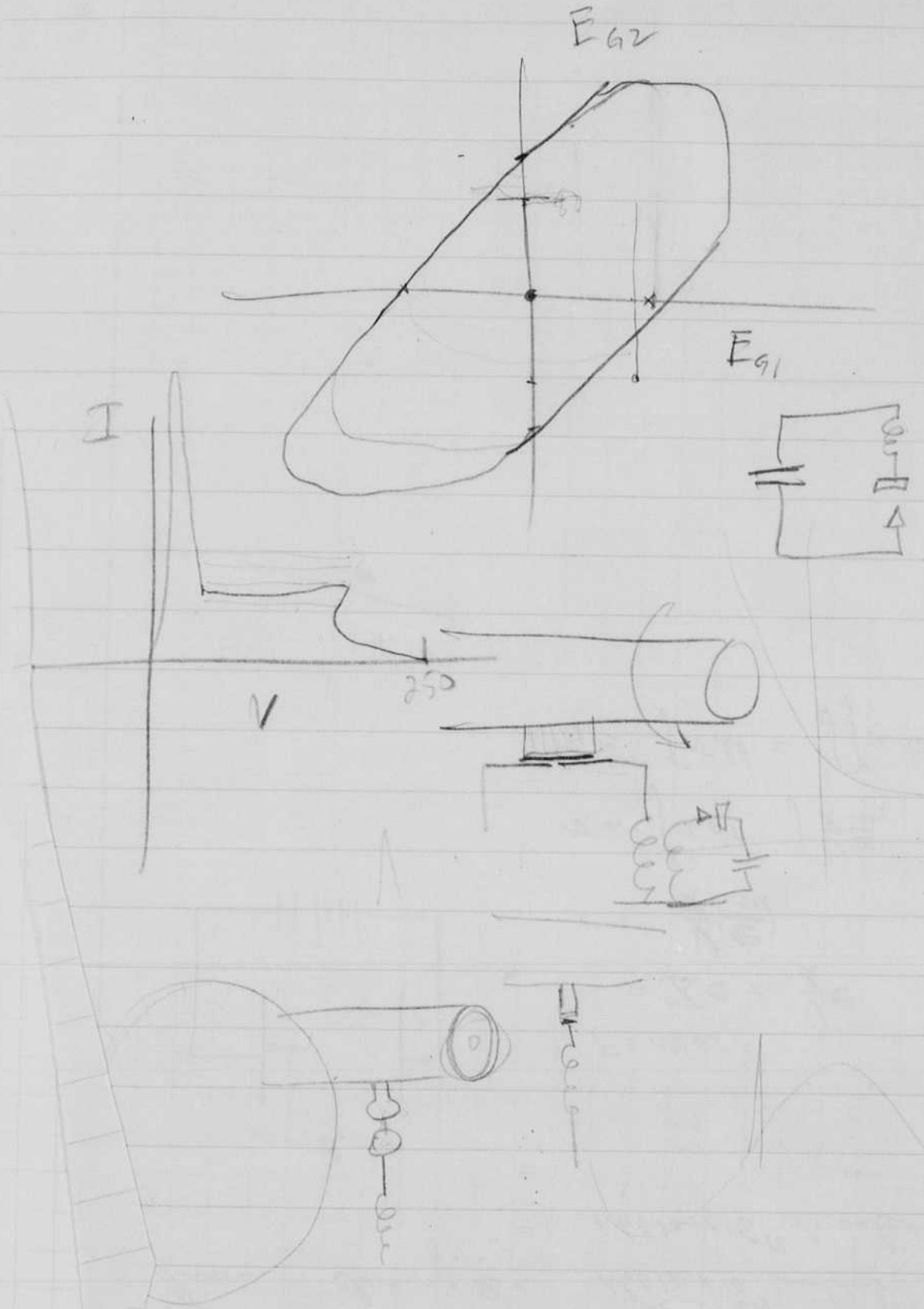
March 1 1937

Mr. Shoultz was here last night and we discussed synchronous motors and control schemes, especially the angle avoiding schemes. This morning we had a talk with Rines discussing in particular the oral discussions with Westinghouse.

I spent the remainder of the day ~~talking to~~ putting down testimony in the Trudeau interference.

Kenneth Beardsley was here on Saturday and Richard Gatti Jr. was here on Friday to give testimony





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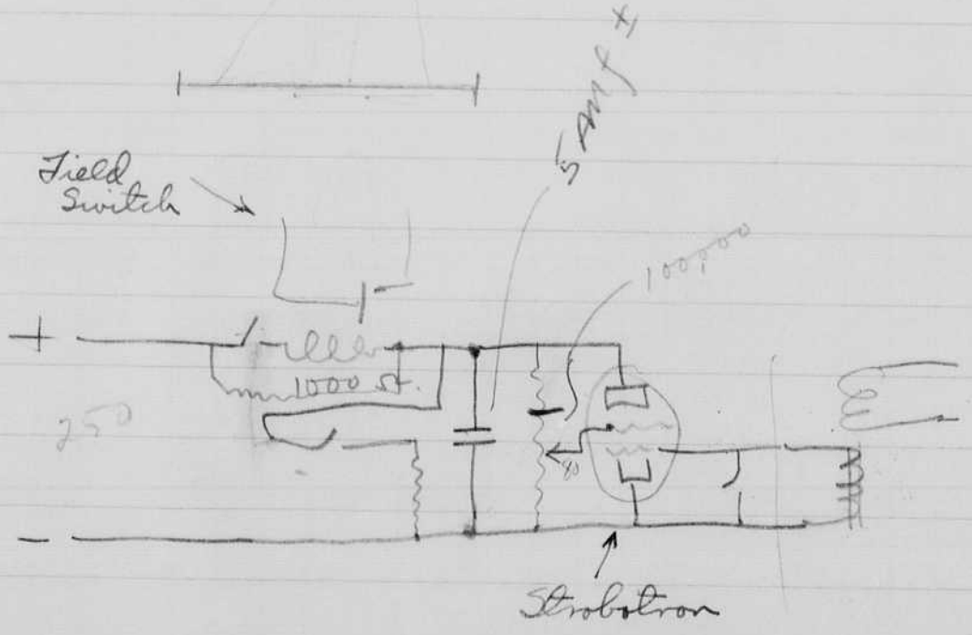
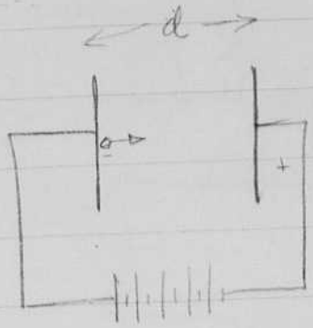


electron charge $e = 1.6012 \times 10^{-19}$ coulomb.

$= 1.6012 \times 10^{-18}$ abcoulomb. e.s.u.

$=$



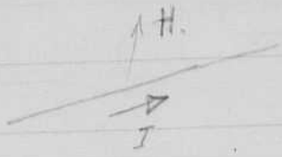
$F = ma$

$= Xe = \frac{V}{d} e$

$a = \frac{V}{d}\left(\frac{e}{m}\right)$

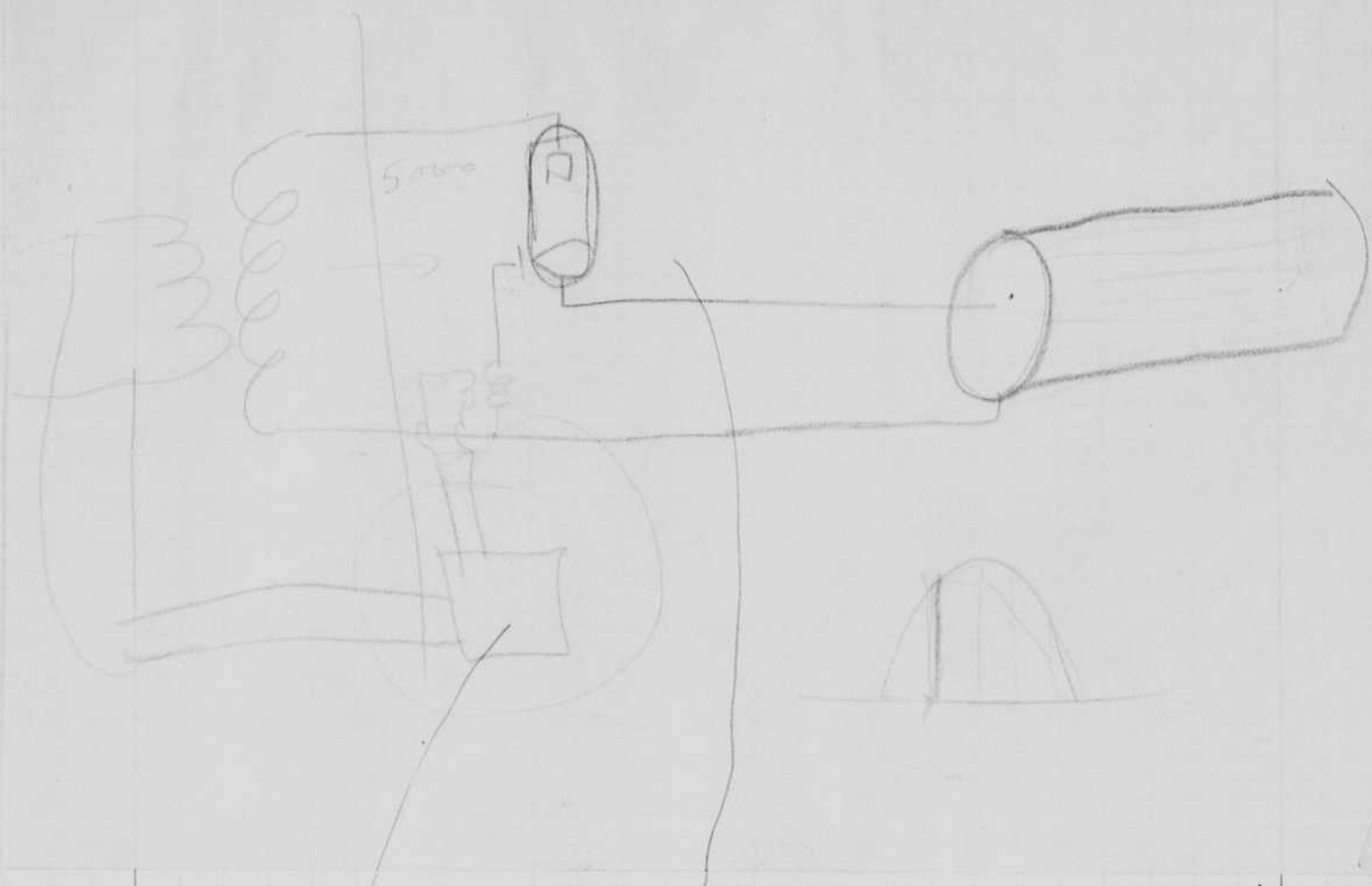
$v = \int a\,dt = \int \frac{V}{d} \frac{e}{m}$

$s = \int v\,dt = \iint a\,dt^2$



The pasted in sheets were used last night in connexion with Shoults.

March 3, 1937.
H. E. Edgerton

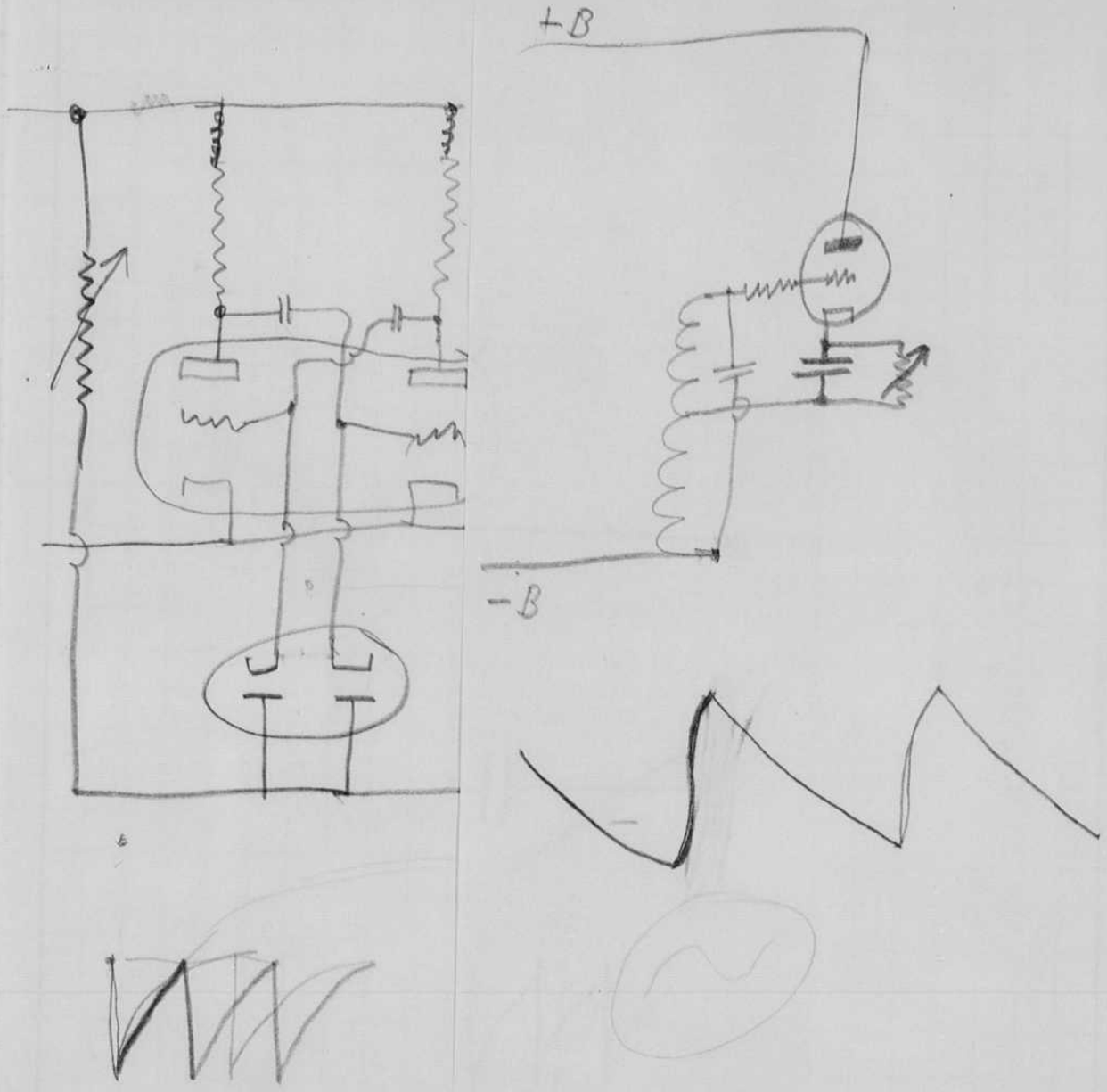


Hg-arc tube

Cable ↑
to be tested.

Circuit for
starting the
cap Hg-arc tube.

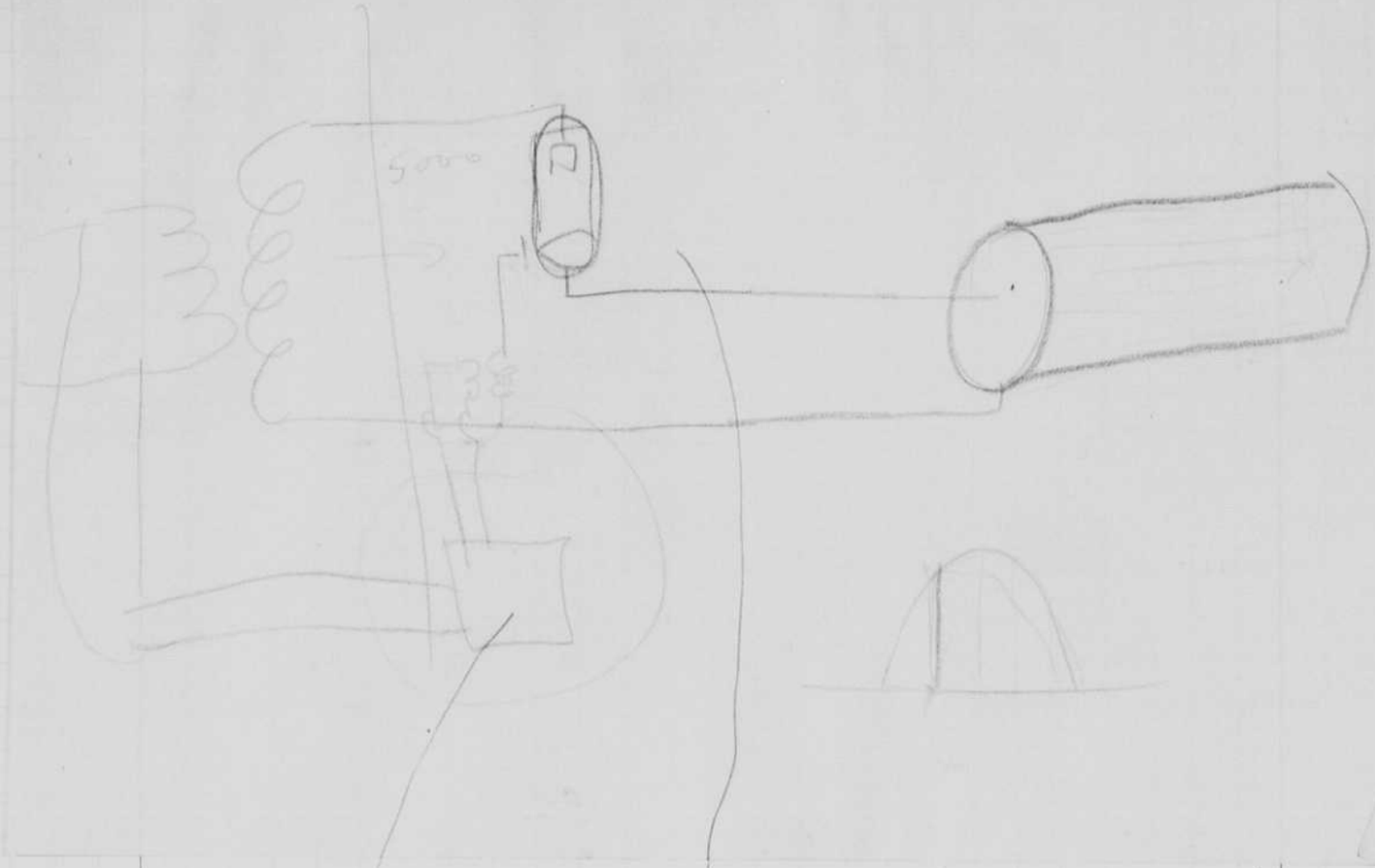
Mr. Alexander and I discussed this cable testing scheme again today. He is going to let me know later when they have a faulty cable to test.



March 4, 1937.

Circuits drawn by Shepard of R.C.A.

March 3, 1937.
H. E. Edgerton



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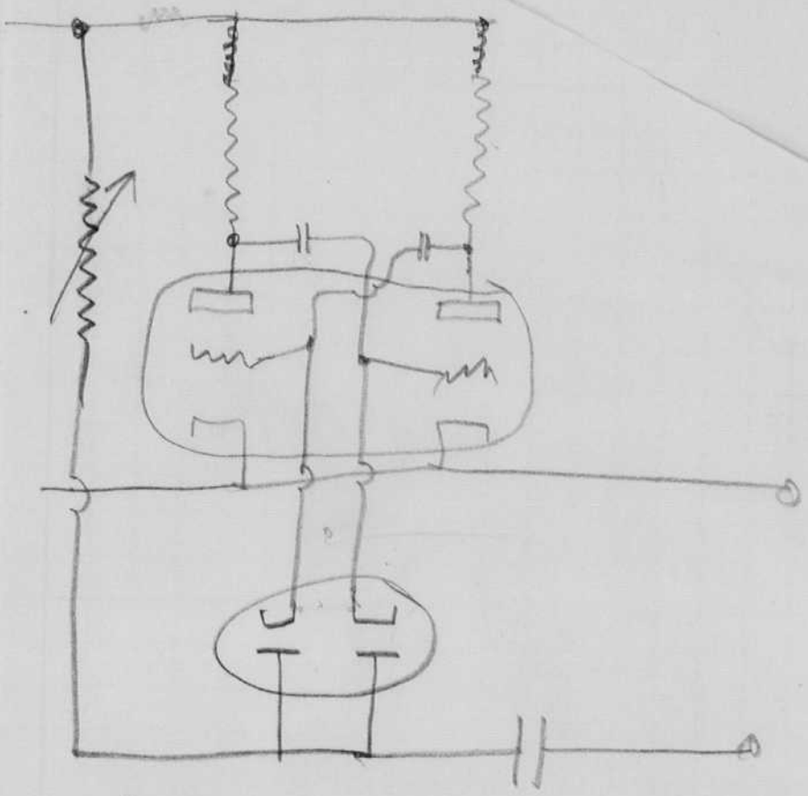

March 4, 1937.

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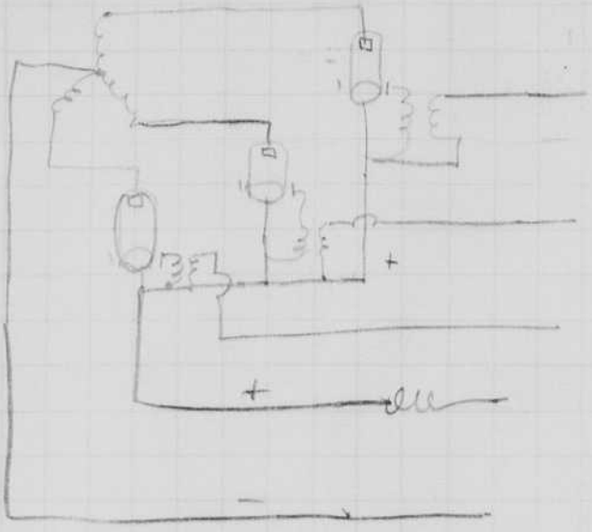
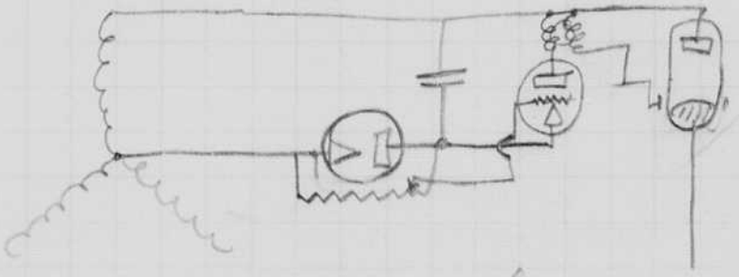
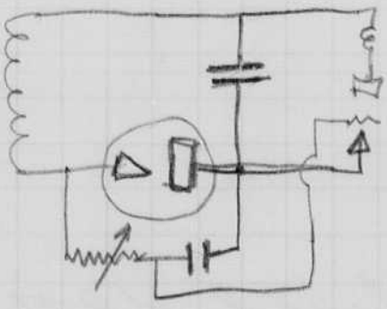
March 4 1937
Harold E Edgerton.

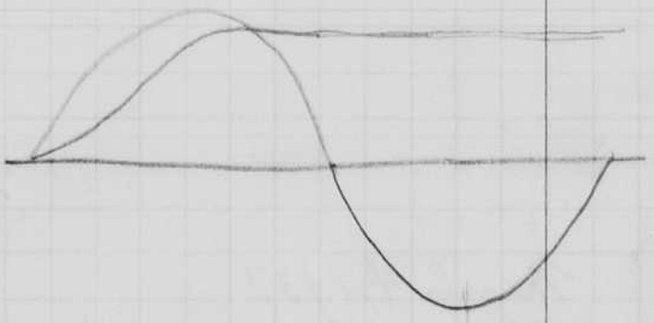
Hg-pool tube 3ϕ rectifier.

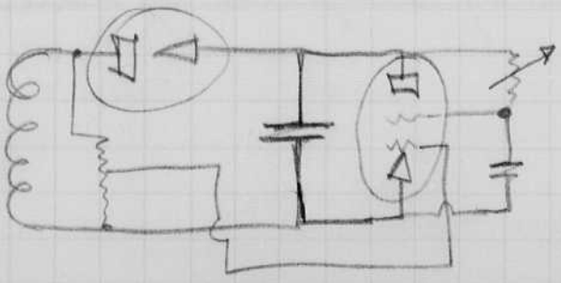


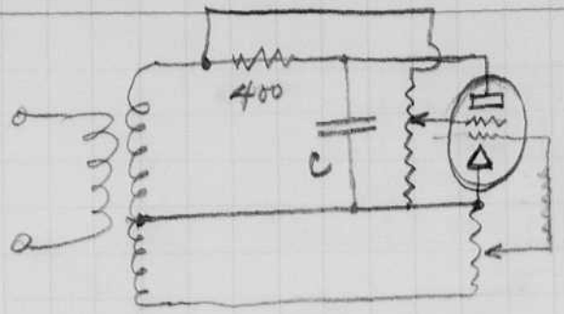


Ditto in other phases





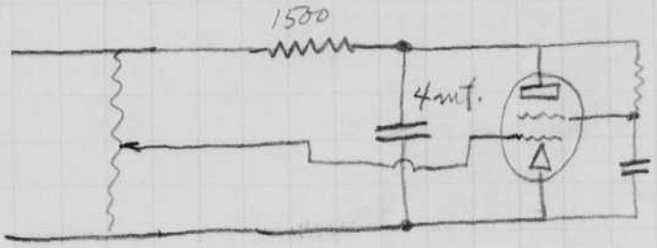


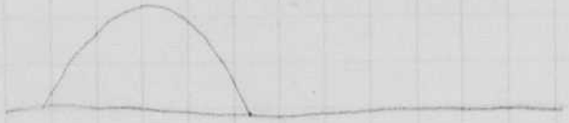


$RC = .01$ sec.

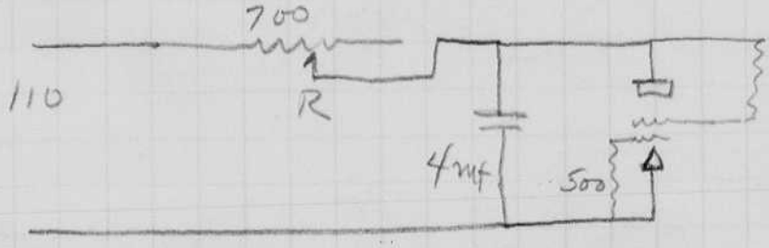
$C = \frac{.01}{R} = \frac{.010.}{400} \times 10^{-3} = 25. \times 10^{-6}$ farads.

let $C = 4$ mf,
$R =$ 1500 ohms.

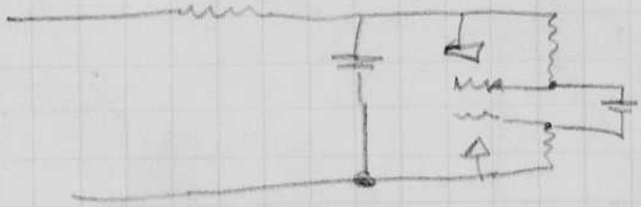




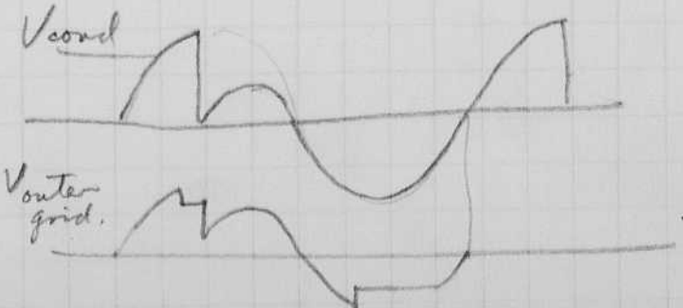
Ciruit wired up as follows.



works ok.



not much advantage.



This shows current to grid before the condenser fires.

I reduced the length of these leads and the operation seemed better at first.

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

$$4\pi^2 LC = \frac{1}{3600}$$

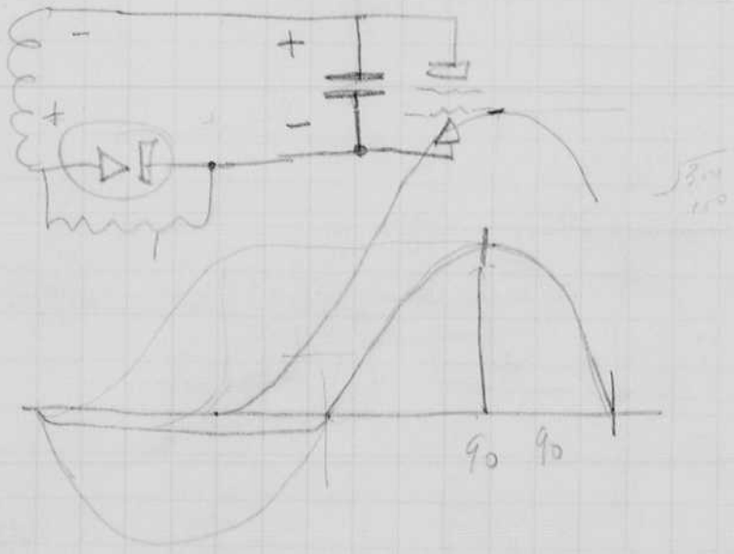
$$L = \frac{1}{3600 \cdot 4 \times 10^{-6} \cdot 40}$$

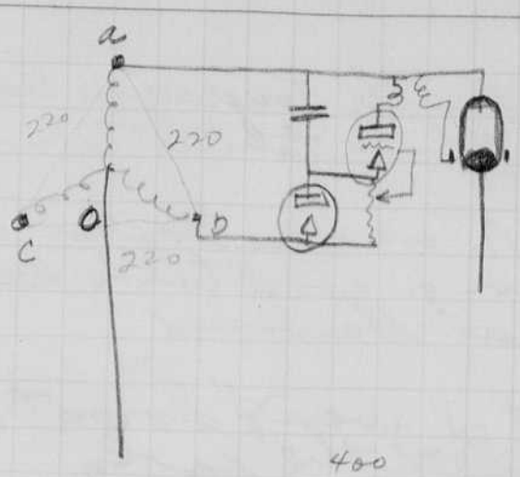
$$\begin{array}{r} .17\text{ h.} \\ .06 \overline{)\,1.00} \\ \underline{6} \\ 40 \end{array}$$

$$\begin{array}{r} 1.6 \\ 4 \\ \hline .004 \end{array}$$

$$L = \frac{1}{3600 \cdot 4 \cdot 10^{-6} \cdot 4 \cdot 1.0} = 1.7\text{ h}$$

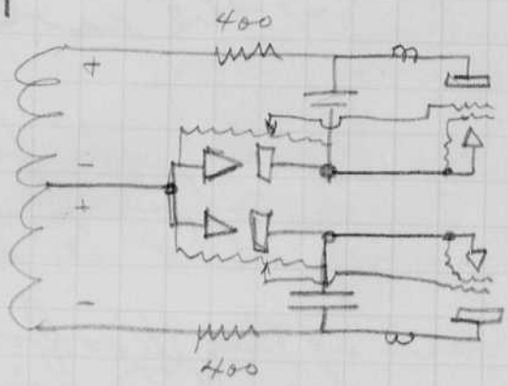
$$\begin{array}{r} 1.6 \\ 1.7 \end{array}$$



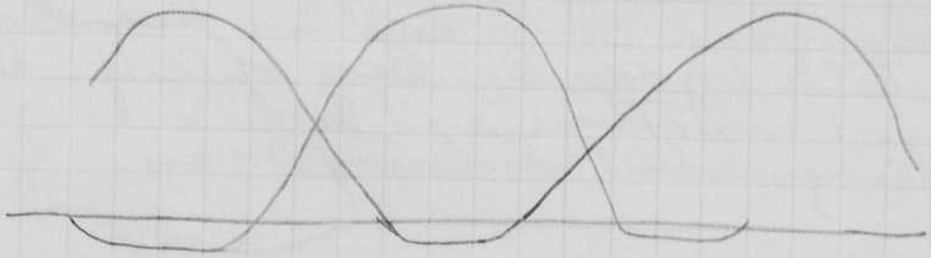


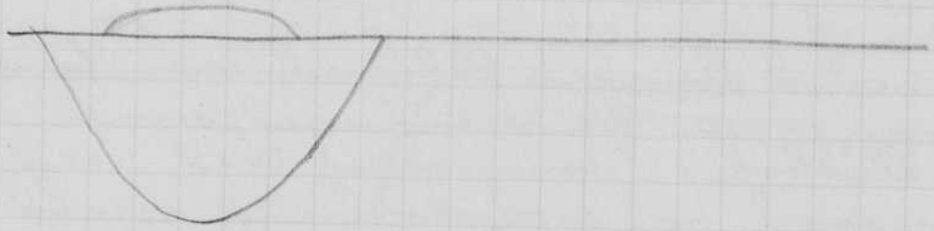
voltage ab lags
voltage ao by 30 degrees.

Ditto circuit on the
three phases.



2 mf 50,000 ~ = 100,000 x 1/5 = .1 mc.





March 11, 1937

Ja. Cl Edgerton.

The interference with Toudescos has been going on since Feb 26 taking testimony.

Shepard of R.C.A. was in Boston on March 4th and gave a good talk ~~last~~ the night before at Harvard

On March 8 I went down to see Spencer about the early stroboscope work.

On March 9 V Bush testified for me in Mr. Rines office. On March 10 Harry Jamme and E. Dahl.

Mr. Woodrow of the Woodrow Radio co took me out to dinner at the Harvard club and we heard a fine talk by ~~Mr~~ Dr. Berg of N.Y. Dr Davis? was there and was a most distinguished looking man.

March 14, 1937

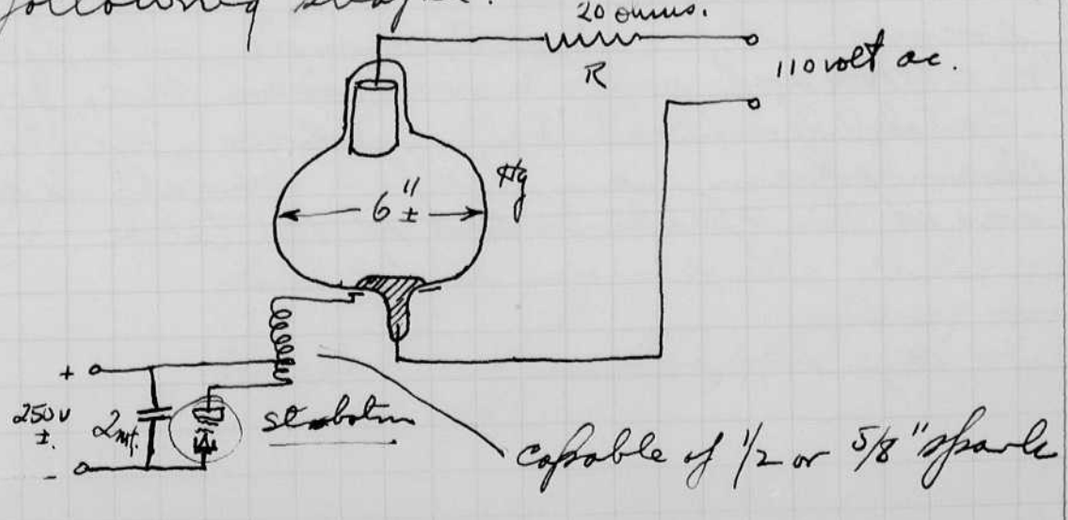
Mary Ellen Welch and their children Richard and William were here on Sat. and today. Velma Jacobs came with them.

I heard Bunker's talk at tech today in Room 10-250. He mentioned some new alcohol (?) compound that was very good for preventing mold growth.

fast photo of a bat in flight.
Supplied by Griffin of Harvard. f 8

Cont'd on 14.1.1937.

On last Friday I put a mercury tube on the excitation from a spark coil in the plate circuit of one of the strobotrons (as p 133) and let it run on life test since. The Hg tube was of the following shape.



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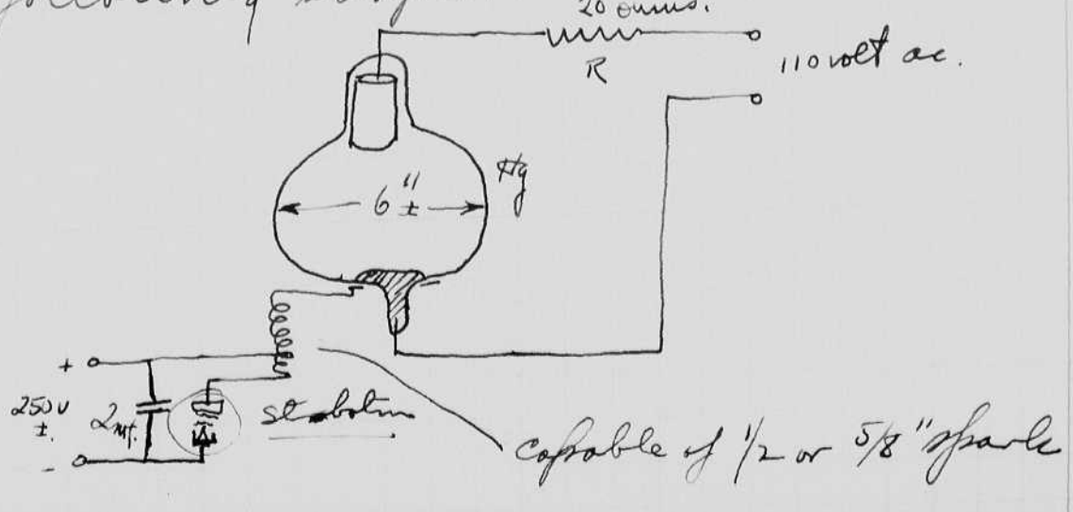
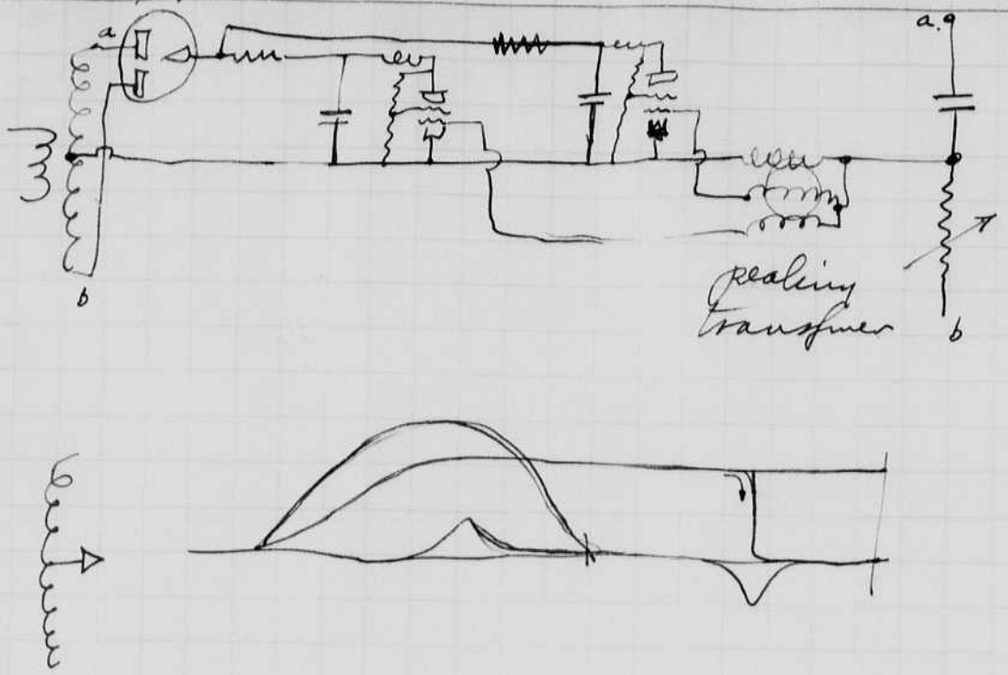


Cont. Mar 17 1937.



March 17 1937 Tuesday.

The tube shown on the bottom of the preceding page has been flickering some. The mercury on the side looks dirty. After shaking it up it works ok. 1/2" spark used. Germeshausen is testing two strobotrons in this circuit which have larger cathodes than are used in the strobotac.

Germs and I went out to dinner last night at the Commercial Club of Boston and the Merchants Club. Mr. Stoughton Bell president. I sat beside Mr. Franklin W. Hobbs and next to him was Mr. John L. Batchelder (coal dealer). 1st Secy - Mr W. E. Chamberlain. Secy. Waldo S. Kendall. Ed Moreland was at the speakers end of the table.

March 19 1932.
K. L.

This morning I talked to the children grades 2-7 at the Shady Hill School. Mrs Chaffee.

Pumped tubes for 545 BR Stolz tonight. Leaky system caused trouble. Pressure of about 1 or 2 cm of argon ok. but holds over on the ~~too~~ low capacity.

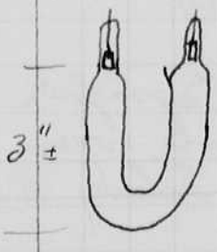
March 21 1937. Pumped quartz tubes yesterday, one straight and the other circular for the microscope. Filled with argon 10" pressure.

Pumped #545 argon tubes today. 2 cm pressure.

Tucker and I took oscillograms of pickup voltage caused by drop of H_2O going through ring. Kicks on oscillograph about the same as that caused by .001 volt 60 cycle a.c.

March 23, 1937. I gave a 5 minute talk on the radio, red network of N.B.C., Allen Miller Chicago made arrangements.

March 25 1937. Spent morning with Rines on 685,501. 6.77 lab. in aft, also pumped tubes and filled with argon at 7" pressure.



Iron electrode.
baked 1½ or 2 hours.
Bombarded electrode.
" " with 1 atm of H_2
" "
Filled with argon ½ atm flashed 10 times with 12 ma 3000 volts.
Pumped out and refilled with 7" argon sealed off.

March 29 1937
Harold Edgerton

three quartz tubes were pumped this afternoon but two of them had cracked seals. The good one was sealed off with 1/2 of an atmosphere of argon.

Mr. Gjon Mili (M.I.T. '27) and Philip Blackburn of the Westinghouse Elect. and Mfg. were here on Friday March 26. 1937. Mili gave a talk on photography and especially lighting with gas filled lamps. He showed a mercury tube which was shorted on the line for a short time. On the second trial he blew the fuses. Tucker rushed out and located the panel. Mr. Moran of the Boston office was there.

Mr. Blackburn invited me to come down to Bloomfield to discuss stroboscopes etc. I believe that I can go on Thursday April 8 when on my way to Bethlehem Pa to talk to the ΣΞ at Lehigh Univ.

March 31. I took a large condenser bank ~~$5~~ ? mf over to Wilkins at P.R. on March 30 to use with the type 548 stroboscope and the new argon lamps. We tried it in the demonstration room. He is going to try to take some photos with it.

April 2 1931 Electronic Conference in Physics dept yesterday and today.

arranged U.S. camera to photograph 400 watt mercury-arc lamp which was shown yesterday by Pound of S.E. Schdy N.Y.

#1 f 2.0
#2 f 2.0 Slower
3 f 6.3. Lens stopped

C. D. Smith of SE Schdy helped take these photos

Notebook # 7

Filming and Separation Record

____ unmounted photograph(s)

5? negative strip(s) inside mounted envelope pg 139

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

was/were filmed where originally located between page 138 and 139.

Item(s) now housed in accompanying folder.

March 29 1937
Harold E. Edgerton

three quartz tubes were pumped this afternoon but two of them had cracked seals. The good one was sealed off with a 1/2 of an atmosphere of argon.

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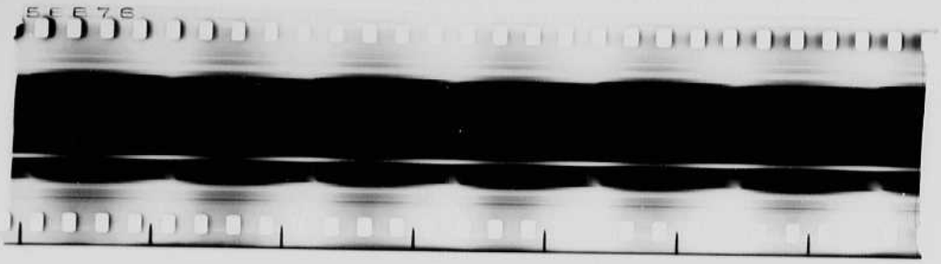
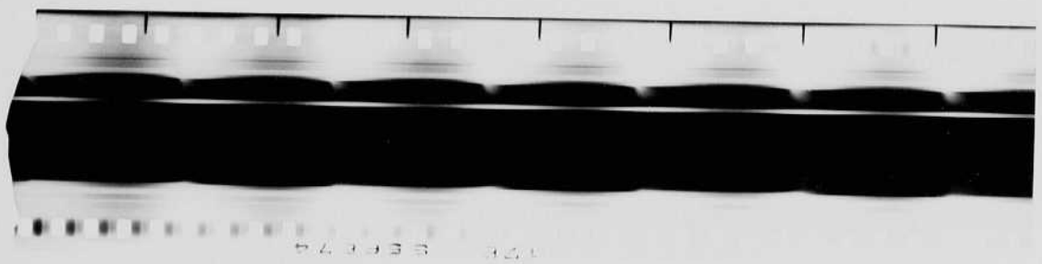
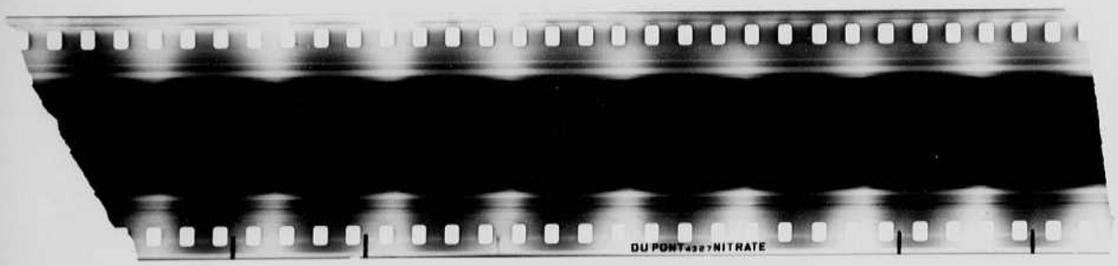
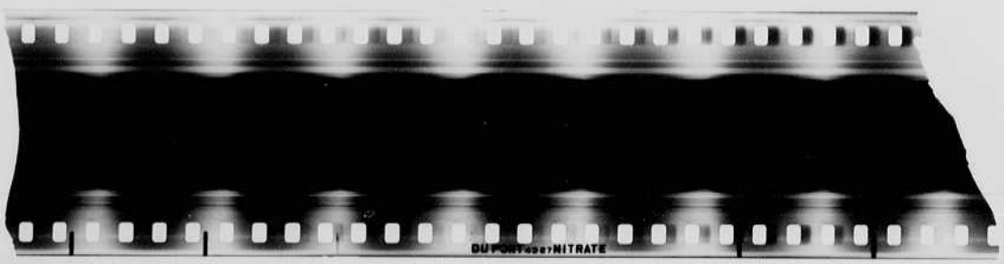





DU PONT 4227 NITRATE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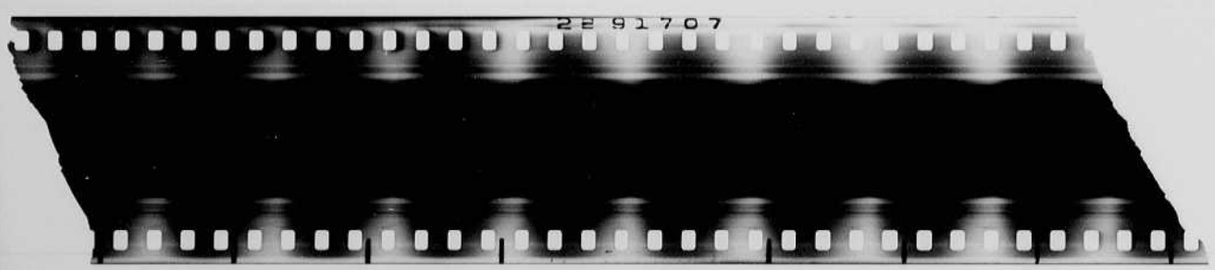
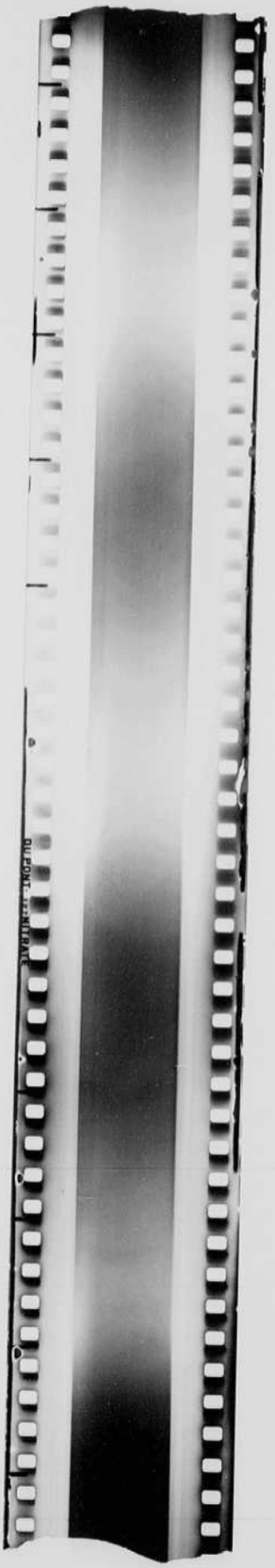
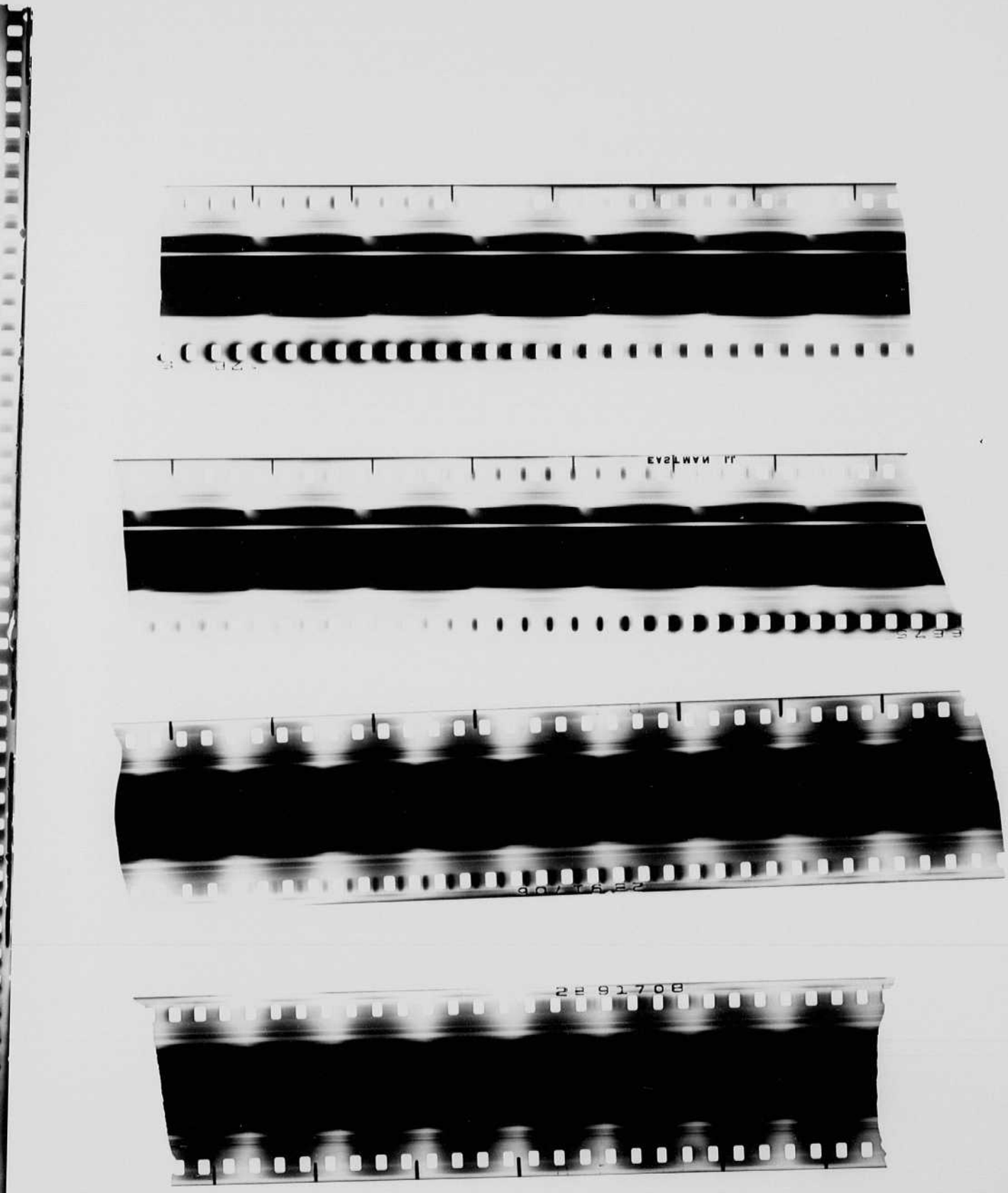

22 91707


DU PONT NITRATE



negs of 400 watt
Mercury lamp.

I gave the one showing the
lamps as it was turned
off to Penty of the
G.E. Vapor Lamp Co.

Hull and Kingdon
visited the lab. after
lunch today and
gave Kingdon two
strobotrons to take to
Schenectady. He said
that he would show
the tubes to Mr. White
in the Vacuum tube
dept.

April 6 1937
D & E Egerton.

Wilkins and I put an argon lamp in the 5 hand clock at G. R. in the afternoon of yesterday. It worked ok and gave more light than the 4g which was replaced.

Wilkins and Scott took photos with a small camera using the 545 and about 45 mf into an argon lamp; lens set f6.3 to f11 with the lamp about 3 or 6 ft from the subject.

A sketch of an argon lamp, 8 watts was sent to Mr. Mailley of the D & E Vapor lamp Co.

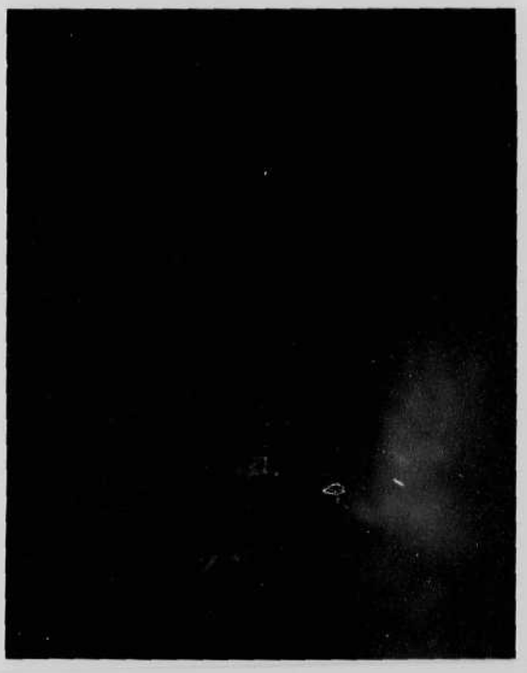
April. 15. 1937 I spent thursday april 8 at the Bloomfield plant of the Westinghouse Co
Mr. Philip Blackburn
Dr. A.M. Hageman Mg of Eng.
Dr R.D. Hall consulting Eng
1 D Dustin tube maker.
V.F. Rydberg. Spec. Sales Unit of nebr 1921.
H. Hufman
Greenbowe Pat. dept.
S. Black mgr.
Rentschler Dir of research
Marder } photog of bullet with
Beese } trailer.
Highriter
Coleman
Watrous also mili

I showed several of them the stroboscope and stroboscope. Discussed ignition starting circuits. Promised to take argon lamps to New York on thursday night, april 23rd, so that he could use them over the week end.

Blackburn took me home to my sister's house in Summit N. J. that night.

R.D. Mailey and Kenty of the G.E. Vapor Lamp Co.

← Jim Rowlands.



Bott furnished by Mr. Griffin of Harvard.

Kingdon and Dr A.W. Hull

Don

April 6 1937

2½ Egerton.

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Grun bowe Pat. dept.

S. Black mgr.

Kentschler Dir of research

Marder } photog of bullet with

Beese } trailer

Highriter

Coleman

Watrous also mili

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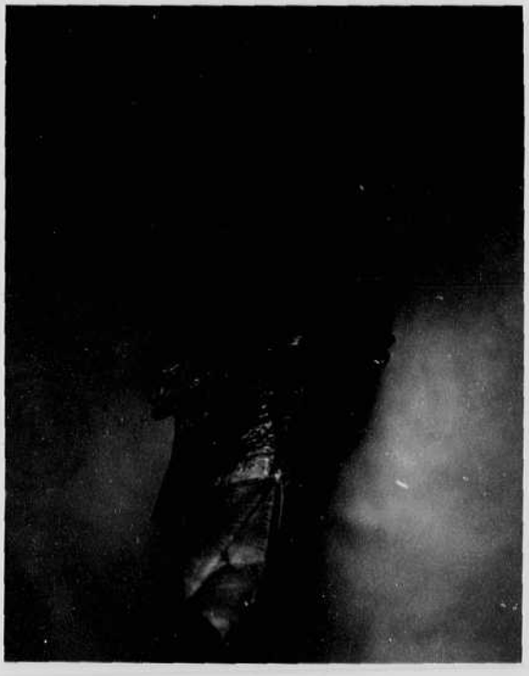
Blackburn took me home to my sister's house in Summit N. J. that night.

R.D. Mailey and Kenty of the S.E. Vapor Pump Co.

← Jim Rowlands.



Bat furnished by Mr. Griffin of Harvard.

Kingdon and Dr A.W. Hull

Don

Apr 15 37 cont.

Mr. Cooley came from Los Angeles on Wednesday and since then he and Tucker and Zemansky have been working on the microscope setup for photographing oil samples to show electrical demulsification.

Griffin from Harvard was here on Monday night April 12 with 6 bats and a photo cell setup by Tucker aided & assisted by Cooley getting the light at the correct time.

April 25. 1937. Mr. Cooley and Mr. Roberts (who came on the 16th of April) worked with us the 16 17 18 and 19 taking high-speed motion pictures of electrical and chemical treatment of emulsified oils. They seemed satisfied with the results and took all the films when they left on the 20th.

I took the double argon lamp flash out fit to New York with me on the night of April 22. Welch helped to carry it to the train. I was met in New York by Gino Milé at 8:30 in the Penn station and took a cab to the Dexter Studio on 47th St between 5 and 6th avenue. Mr. Arthur Murray was at this studio and we set up the flash out fit in the main part. Bill Jackson did the developing. Two models performed. One shot a bow and arrow as she jumped into the air. The other jumped into the air and the picture was taken at that instant.

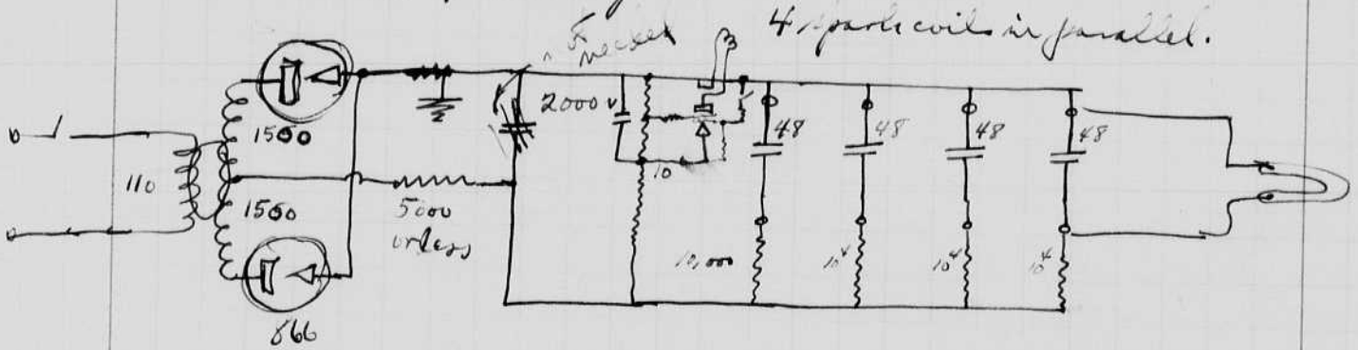
One lamp had 36 mf at 3000 volts on it and was placed quite high at the side with the reflector at a 45° angle, seven ft from the subject. The other lamp was 12 ft from the subject and was located at the camera. A 12 mf condenser was across it.

The first picture was taken at f 6.3 on orthochromatic film and the exposure was ok with 12 minute development. Other shots were taken on 35 mm film with the same setting and the exposure was about the same.

The circuit of the flash unit is on page 75 with minor exceptions, for instance there is only one slot for firing both spark coils.

More light is needed so that photographs at f 8, 11, & 16 of large subjects can be taken. Reflectors with more efficiency will help greatly. I would like to see about 10 times as much light, and it can be obtained by means of more condensers and lights.

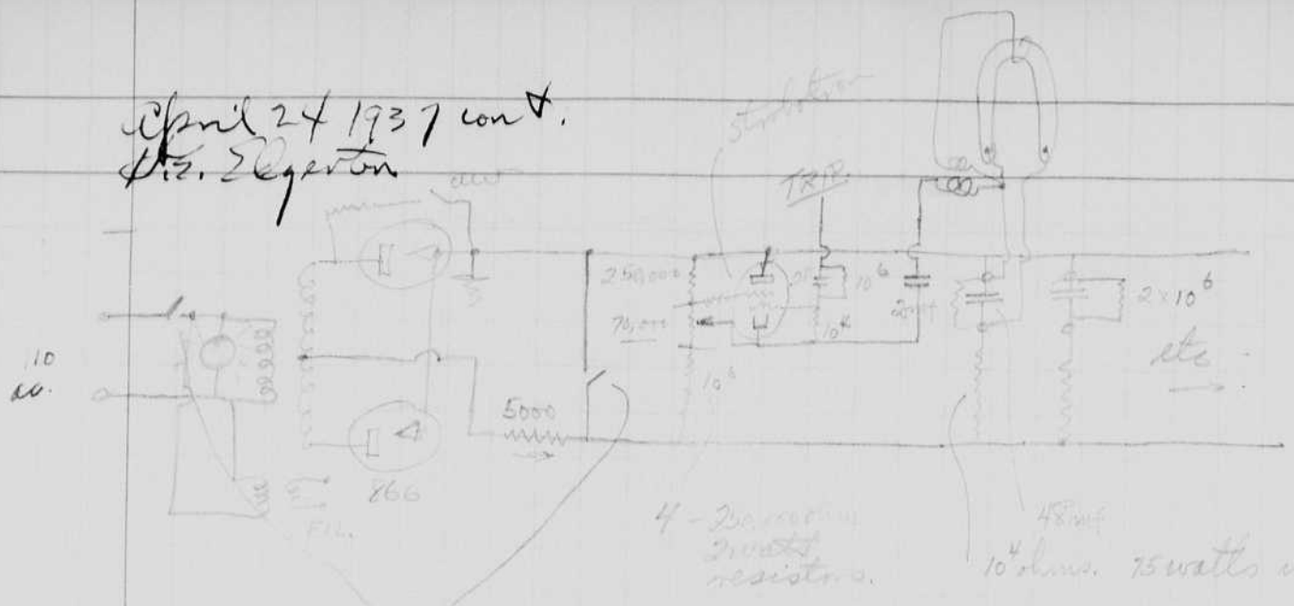
I am going to ~~try~~ design a new unit with 48 mf at 2000 volts on each lamp. and with 4 lamps.



The spark coils should be put in series with condensers as in the unit I used, so that the spark will be the same no matter how many lamps are used. A 2 meg ohm leak should be put across each of the 48 mf condensers. $RC = 48 \times 10^{-6} \times 2 \times 10^{6} = 96$ seconds.

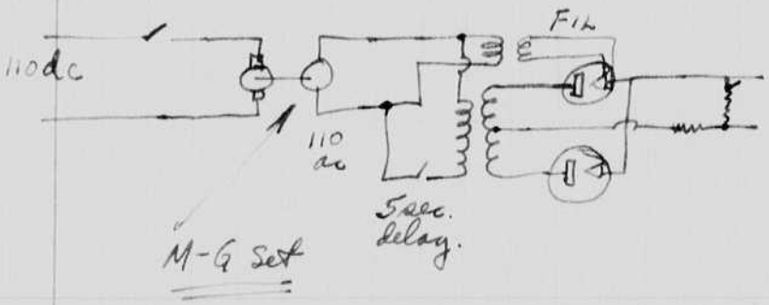
On the evening of Apr 23 I gave a talk at the Physics Club in Philadelphia at the Univ of Pa. I stayed that night with Mr. Henry B. Allen. Dinner at the Rittenhouse Club with Dr. Barnes and Mr. Allen. John Bancroft about to be engaged to Allen's daughter

April 24 1937 con't.
Mr. Edgerton



the two switches are to be ganged together so that the shorting switch closes when the power switch is off.

If used in a d-c district a motor-generator set will be needed.



The short circuiting switch should be a relay arranged to drop shut when the plate transformer is off. It would be connected across the primary of the plate transformer.

April 29 1937.

Last night I pumped some tubes for the 545 stroboscope. they were sealed off with about 1 or 1½ cm of neon (1) and argon (3) and a mixture (1).

Also made two lamps for flash machine. One with 2 cm of neon & 8 of argon, the other with 4 cm of .. and 8 of argon. The neon brings in some red and yellow which balances the color of the flash.

A & M Roberts
Wetzlite Co.

&

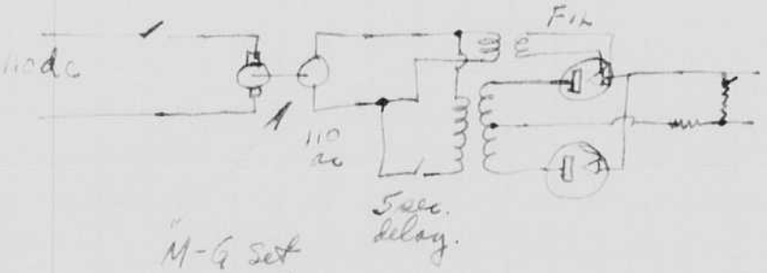
Mr. Cooley. Los Angeles.

Movies for Prof. Mead today f 2. 1½ mf 1000 V
Rubber with 400/sec.
Paraffine to show
growth of cracks.

movies of air bubbles flowing up thermos D.S.O
f 3.2 2 mf 1000 volts.
about 500/sec.

April 24 1937 cont.
Dist. Edgerton

If used in a d-c district a motor-generator set will be needed.



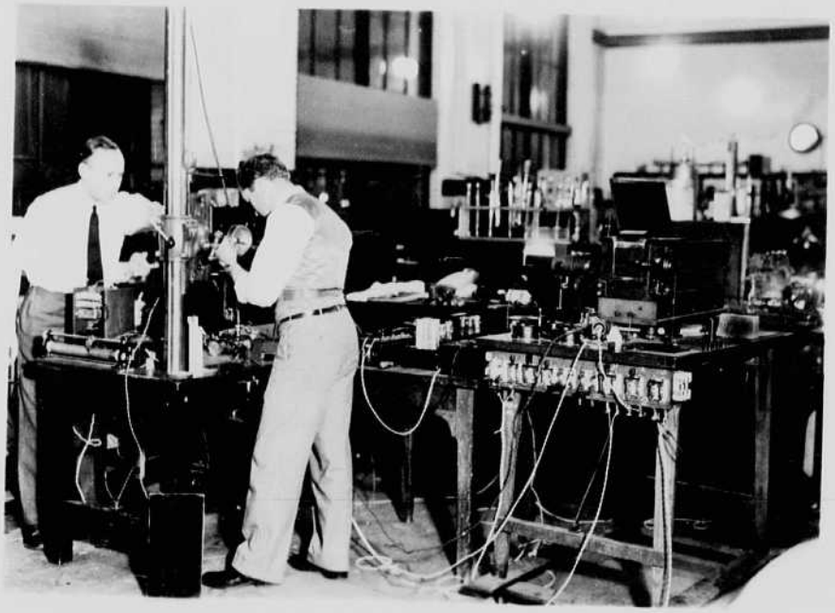
M-G set

The short circuiting switch should be a relay arranged to stop spot welder when the main switch is off. It would be connected across the primary of the welding transformer.

April 29, 1937.

Last night I pumped some tubes for the 5" oscilloscope. They were sealed off with about 1 or 1½ cm of neon and argon (3) and a mixture (1).

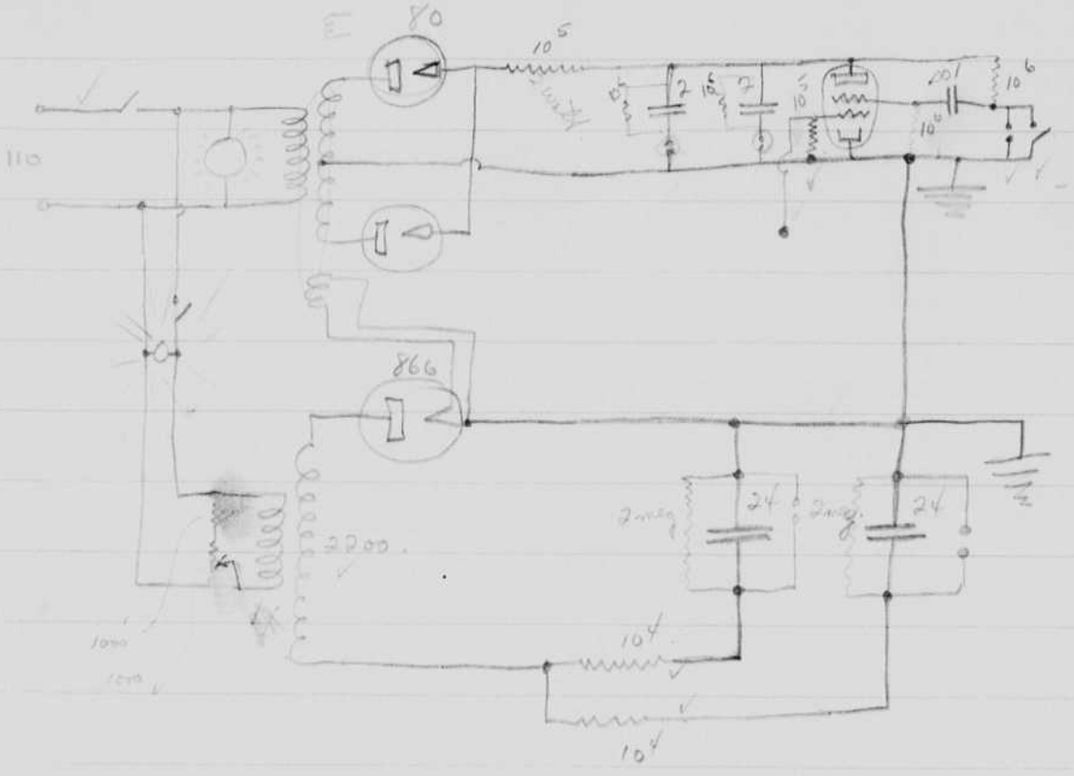
Also made two lamps for flash-machine. One with 2 cm of neon & 5 of argon. The other with 1 cm of ... and 5 of argon. The neon brings in some red and yellow which balances the color of the flash.



Movies for Prof. Edgerton Tuesday f 2. 1½ sec 1000 ℓ
Camera with 400/sec.
Pump for slow
growth of crystals.

Movies of air bubbles flowing after night Dec 0
f 32 2 sec 1000 watts.
about 500/sec.

Speedlight.



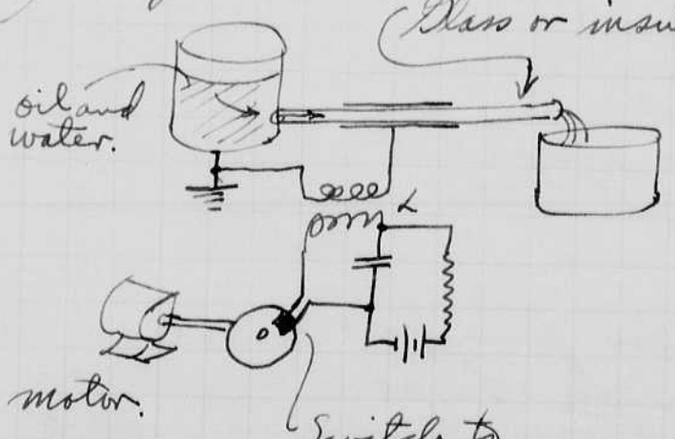
May 4, 1937.

May 6 1937.
H. E. Edgerton.

I spent the last few days rebuilding the old spark machine which was in the oscillograph case. Before we had 4 - 12 mf 660 volt oil condensers in series on an open spark. 16000 volts. Now these are in parallel 48 mf and they charge to about 3800 volts. 1.38×10^6 ohms $\times$ 2.8 ma = 3860 volts. A strobolite is used as a trip as in the diagram on p 146. The new circuits works fine. I used a tube having 4 cm of neon and about 8 cm (+?) of argon which gives a good color. This lamp with neon and argon does not "check" on the inner surface of the glass as do the lamps with argon.

Oil treatment to remove water

The below method should be especially good for treating oil with large amounts of water which is highly conducting. The emulsion of water and oil are driven through glass tubes about which are external electrodes. A high voltage is impressed on the external electrodes for a very short interval of time in order to treat the oil and break down the emulsion. Circuits similar to those that we use for our stroboscopic lamps should be well adapted for this purpose.



The breaker circuit can also be similar to auto ignition circuits that break a current.

May. 10 1937.

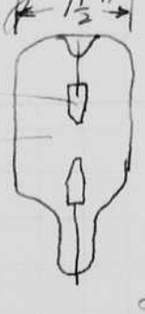
Esther and I went to Hanover. N.H. on Friday where I talked to the Dartmouth Scientific association. We stayed at the home of Prof. E. F. Hull. About 200 attended the lecture. I met Mr. Browne who is going to M.I.T. next year, also several others.

May 19, 1937.

On Friday May 14 I was scheduled and talked to the G. E. Research colloquium on stroboscopic light. I had an outfit with me for demonstrations. I met several people in the labs and around the plant.

On Monday May 17 I went to Worcester and talked to the ?? Co ?? machine shop. Mr. Bliss was president. Mr. Burt of the ? co talked.

May 26, 1937. Last class today (6:02 Juniors). C.I. section. Exams start tomorrow.
Grier and I pumped a tube today for use in the grinder test apparatus for the Norton Co. It turned black after about 10 minutes of operation. This probably was due to water vapor in both the argon. 1 atmosphere of argon was too much pressure. The arc would bow out to the side of the tube.



I also pumped a tube for the 548 – 3cm of pure argon gas. I believe that more could be used, say 7 cm.

May 26 37 cont.

Gin Mili was in the lab. on Saturday the 22 and we all discussed speed photography in studio work. Mili wants a large outfit to use in New York for six months to try to get a striking set of photos.

May 28 1937

Kids f6.3 - 1/60 sec and 1/40 sec
Kodachrome 35 mm by Leica
Neon & argon wire lamp
24 mf 4000 watts
3 ft ℄ reflector to subject
Ansco Speedex chart & Bennehausen
f 6.3
f 5
f 12.5

June 1, 1937. Pumped argon lamps today

Standard 548 size with 3 cm.

Long 10 or 12" (1 cm) for G.R. about (1/2 cm) or more argon.

Quartz 1/2 inch capillary 3 mm I.D.

Wagniger made quartz lamp today and also made a quartz manifold.

I also pumped two tubes pyrex, 1" cap 3 mm I.D. and filled to 1 atmosphere. This pressure was too high for the mercury-Grinder apparatus.

School is almost over, tomorrow the laboratory exam, Monday graduation Tuesday alumni day.

Refilled to 20 cm - too low - ~~bulb~~ Self operator.
" " 40 " - O.K. but tube cracked.

List Prepared by Mrs. Goodrich
Feb. 25, 1937.

PUBLICATIONS BY H. E. EDGERTON

The Pulling-Into-Step of a Synchronous Induction Motor.
(with F. J. Zak)
I.E.E. Jour., 68, pp. 1205-10, September, 1930.

Transient Torque-Angle Characteristics of Synchronous Machines.
(with W.V.Lyon)
A.I.E.E. Trans., Vol. 49, pp. 686-99, 1930.

The Mercury Arc as a Source of Intermittent Light.
Jour. Soc. Motion Picture Engineers, Vol. XVI, No. 6, p. 735, June, 1931.

The Pulling-Into-Step of a Salient-Pole Synchronous Motor.
(with P. Fourmarier)
A.I.E.E. Trans., Vol. 50, pp. 769-81, 1931.

Stroboscopic and Slow-Motion Moving Pictures by Means of Intermittent Light.
Jour. Soc. Motion Picture Engineers, Vol. XVIII, No. 3, p. 356, March, 1932.

Stroboscopic Photography.
(with K. J. Germeshausen)
Electronics, 5, pp. 220-21, July, 1932.

The Mercury Arc as an Actinic Stroboscopic Light Source.
(with K. J. Germeshausen)
Rev. Sci. Instr., 3, pp. 535-42, October, 1932.

Synchronous-Motor Pulling-Into-Step Phenomena.
(with G. S. Brown, K. J. Germeshausen, and R. W. Hamilton)
Trans. A.I.E.E., Vol. 52, No. 2, p. 342, June, 1933.

Stroboscopic-Light High-Speed Motion Pictures.
(with K. J. Germeshausen)
Jour. Soc. Motion Picture Engineers, Vol. XXIII, No. 5, p. 284, November, 1934.

The Stroboscope and High-Speed Motion-Picture Camera as Research Instruments.
(with K. J. Germeshausen)
Am. Inst. Chem. Eng., 30, pp. 420-37, 1934.

High-Speed Motion Pictures.
Electrical Engineering, Vol. 54, pp. 149-53, February, 1935.

Study of the Flow of Air with a Stroboscope.
Mechanical Engineering, 57, pp. 228-29, April, 1935.

A Stroboscopic Power-Angle Recorder.
Electrical Engineering, 54, pp. 485-88, May, 1935.

High-Speed Photography.
(with K. J. Germeshausen and H. E. Grier)
The Photographic Journal, London, 198, April, 1936.

The Application of the High-Speed Motion-Picture Camera
to Research on the Surface Tension of Liquids.
(with E. A. Hauser, B. M. Holt, and J. T. Cox, Jr.)
Jour. Physical Chemistry, Vol. 40, No. 8, November, 1936.

A Cold-Cathode Arc-Discharge Tube.
(with K. J. Germeshausen)
Electrical Engineering, Vol. 55, No. 7, pp. 790-794, 809, July, 1936.

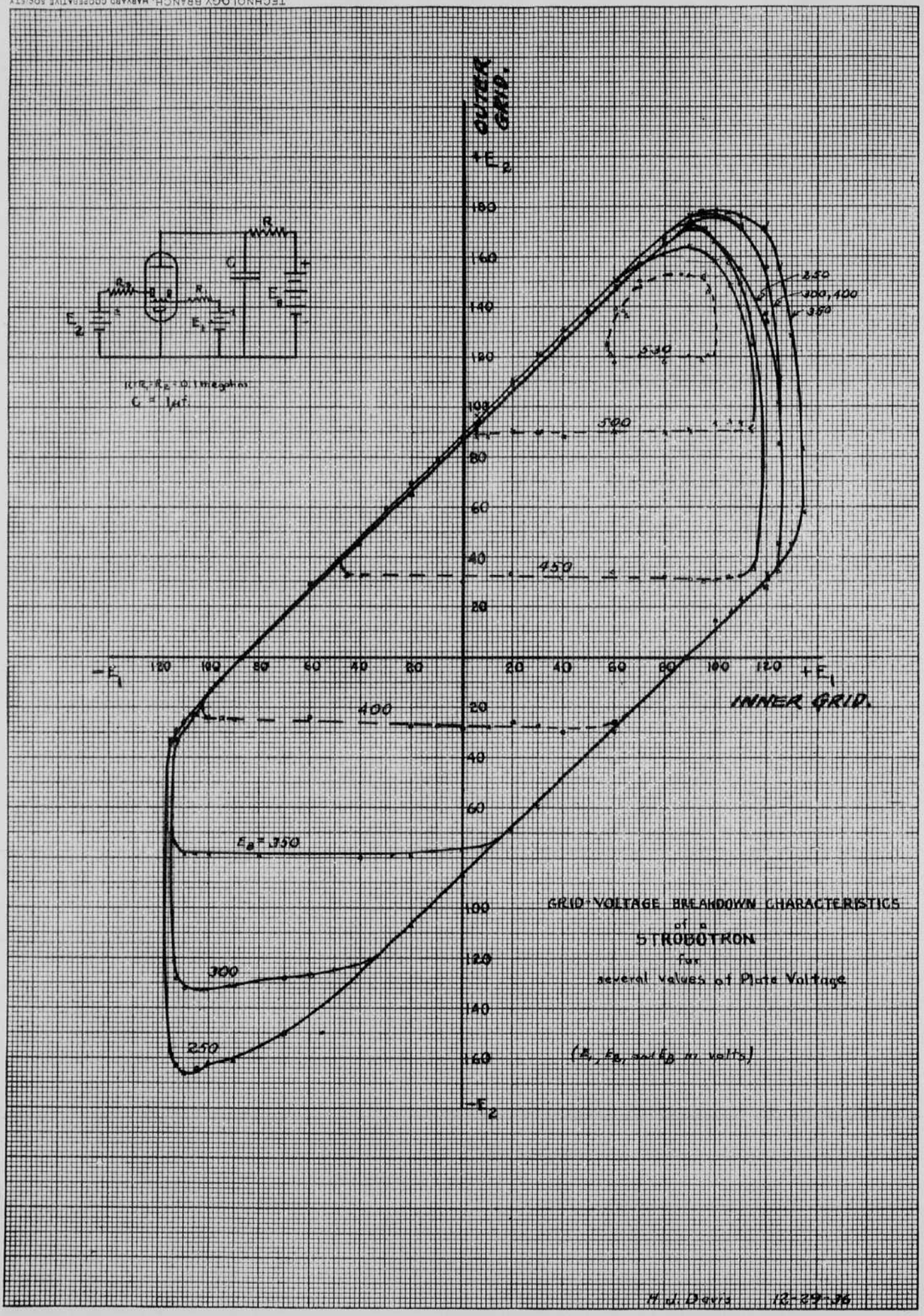
A Direct-Reading Counting Rate Meter for Random Pulses.
(with N. S. Gingrich, and R. D. Evans)
R.S.I. Vol. 7, p. 450, December, 1936.

High-Speed Photographic Methods of Measurement.
(with K. J. Germeshausen and H. E. Grier)
Jour. Applied Physics, Vol. 8, No. 1, p. 2, January, 1937.

The Strobotron.
(with K. J. Germeshausen)
Electronics, Vol. 10, No. 2, p. 12, February, 1937.

The Strobotron II
(with A.B. White W.B. Nottingham and K.J. Germeshausen)
Electronics Vol 10 no 3 pp 18 March 1937.

Half-Cycle Sp.T. Welder Control T.S. Gray W.B. Nottingham
Rev. Sci. Inst. Feb 1937 page 65.



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2. time delay circuit for spark machine.
3. Oscillograph amplifier for dc currents. all ac power supply.

Notebook # 7

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(notes, drawings, letters, etc.)

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Half-Cycle Spot-Welder Control

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A circuit for controlling a small spot-welder is described which utilizes simple, inexpensive, cold cathode tubes. Variation of the welding heat is accomplished by control of the fraction of a single half-cycle during which current is supplied to the welder transformer. Increased pressure is found to be necessary for satisfactory welding.

Introduction

IT is generally recognized by the research worker who uses a spot-welder in the construction of special apparatus that a high current applied[2] for a precisely determined and very short period of time is desired for welding operations.[3] Commercial equipment no doubt meets the demands of many of the users of large spot-welders; however, it has long been felt that a simple circuit which could be adapted to standard low power welders (1 to 3 kva) would be of value. Circuits of this type have been experimented with by one of us (WBN) for the past three years with the final result that the one described here is considered by us to be both the simplest, cheapest, and, at the same time, the most reliable of all those tried. It has been used extensively at this institute in both the physics and electrical engineering departments.

Strobotron and Band-Igniter Arc Tubes

In this circuit, which is shown in Fig. 1, the two elements of prime importance incorporated are the "strobotron" (T_2) and the "band-igniter arc tube" (T_1). The band-igniter arc tube is shown schematically in Fig. 2, and consists of the simplest pool-type mercury arc. We have given our tubes a careful exhaust, using vacuum-distilled mercury distilled over to the tube after it has been thoroughly baked. The anode was heated by induction, and the tube finally operated for some hours while on the pumps before it was sealed off. The development of this tube dates back at least to Peter Cooper Hewitt,[4] but has

[1] Collaborators in this development to whom the authors are greatly indebted are H. E. Edgerton, K. J. Germeshausen, M. R. Saslaw and A. B. White, all of M. I. T.

[2] The polarity is important in certain cases of dissimilar metals.

[3] H. W. Lord and O. W. Livingston, Electronics 6, 186 (1933).

[4] U. S. patents No. 682,691, Sept. 17 (1901); No. 955,460, Apr. 19 (1910).

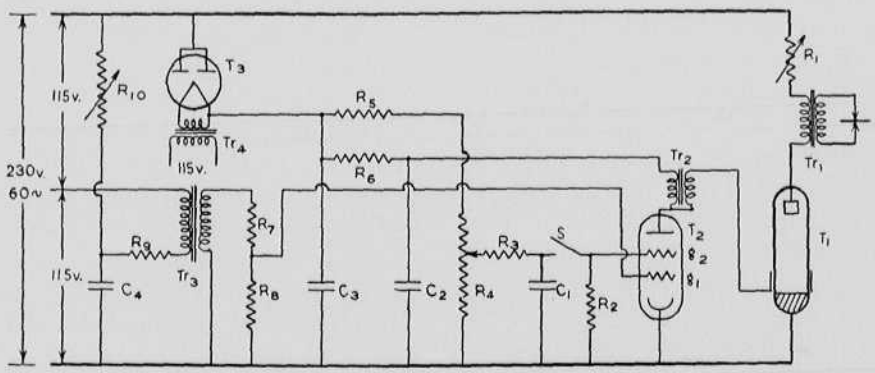

FIG. 1. Diagram of the circuit for half-cycle control of a spot welder.

T_1—band-igniter mercury arc tube
T_2—strobotron
T_3—type 80 tube
Tr_1—welder transformer
Tr_2—Ford spark coil assembly No. 18-12024-A
Tr_3—peaking transformer
Tr_4—filament transformer
C_1—0.5 mf (paper, 200v)
C_2—4.0 mf (paper, 400v)
C_3—8.0 mf (electrolytic, 450v)
C_4—1.0 mf (paper, 600v)
R_1—10 ohms
R_2—100,000 ohms
R_3—200,000 ohms
R_4, R_5, R_7, R_8—50,000 ohms
R_6—20,000 ohms
R_9—5000 ohms
R_{10}—5000 ohms (50 watt)

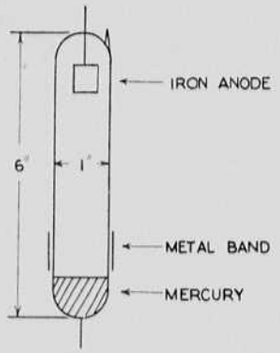

FIG. 2. Band-igniter mercury arc tube.

recently been used extensively by H. E. Edgerton[5] and his collaborators.

Since the strobotron has been developed quite recently,[6] and although it is closely related to the "grid-glow tube" and the "thyratron," a short explanation of its operation is perhaps justified. Fig. 3 shows the four essential elements, which are (1) cathode, (2) an inner grid, (3) an outer grid, and (4) an anode. All leads are connected to the four prongs of a standard radio tube base.[7] The type of discharge observed in the tube may be either a glow or an arc, depending on the current conducted.

Typical characteristics as tabulated elsewhere[8] are in Table I.

More detailed information as to the operation of one of these tubes may be had from a typical diagram of the starting characteristics[8] shown in Fig. 4. In many cases, the anode-cathode voltage is constant and set by the circuit. Either of the grids, or both, may be varied in their potential with respect to the cathode to start the discharge. Such conduction is initiated when the difference of potential between any two elements exceeds values characteristic of the tube as tabulated in Table I. The potential of the grids with respect to the cathode can be located on a two-dimensional diagram, as shown in Fig. 4. The loop of this diagram encloses the region of nonoperation for an anode potential of 320 volts.

To illustrate this, let it be assumed that the

[5] Edgerton, Germeshausen and Grier, J. App. Phys. 1, 2 (1937).
[6] Germeshausen and Edgerton, Elec. Eng. 55, 790 (1936).
[7] The name and address of the distributor of these tubes will be furnished on request.
[8] A. B. White, W. B. Nottingham, H. E. Edgerton and K. J. Germeshausen, Electronics, March (1937).

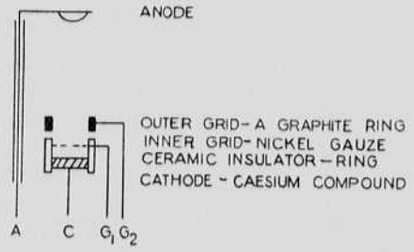

FIG. 3. Arrangement of elements in the strobotron.

potential of the outer grid is set at any arbitrary value, such as +70 volts measured from the cathode. The vertical dotted line through the point +70 on the horizontal axis cuts the loop shown at −25 volts and at +125 volts. This means that as long as the inner grid voltage is between these limits when the anode potential of 320 volts is applied, the strobotron will remain nonconducting. Conductivity sets in, however, in case the inner grid is made more negative than −25 volts, or more positive than +125 volts. Thus, if any arbitrary values be assigned to the inner and outer grid potentials and the corresponding point be located on the plot shown in Fig. 4, it will be seen at once whether or not the tube will conduct depending on where the point falls. If the point falls inside the loop, then the strobotron *does not conduct*. If the point falls outside the loop, then the tube *does conduct*.

OPERATION OF WELDER CIRCUIT

The circuit shown in Fig. 1 is designed to operate from a mid-tapped 230-volt 60-c.p.s. line. The heavy lines of the figure show the connection to the welder-transformer primary in which the mercury tube, designated by T_1, serves as a simple switch. The strobotron circuit serves to deliver to the starting band on T_1 a high voltage pulse accurately timed with respect to the 230-volt 60-c.p.s. wave normally impressed across T_1, thus causing it to become conducting for that fraction of the positive half-cycle which remains after the starting-band pulse is delivered. Fig. 5 shows the voltage wave-forms in the circuit as observed with a cathode-ray oscilloscope. The arc extinguishes itself at the end of the half-cycle and the tube remains nonconducting until another pulse is delivered to the starting band.

The type 80 rectifier tube T_3 serves to charge up the 4 mf condenser C_2 which, when discharged through the strobotron and the primary of the Ford spark coil Tr_2, generates the high voltage pulse used by the starting band to set up the arc in the mercury tube T_1.

Between welding operations, the outer grid of the strobotron is maintained at cathode potential (i.e., zero) while the inner grid has impressed upon it a 60-cycle "peaked" wave of a maximum amplitude of about 50 to 60 volts obtained from a potential divider $R_7 - R_8$ across a peaking transformer[9] Tr_3 whose primary is supplied from a "resistance-condenser" phase shift circuit R_{10} and C_4. The negative peak of this wave, with respect to the positive peak of the line voltage, can be varied at will from 20° to 160° lagging. Referring to Fig. 4, we see that as long as the outer grid potential is zero, the point representing the inner grid potential remains inside the loop for all parts of the cycle. Line *ab* represents the locus of this point. When the welding pulse is desired, the switch S is closed. At the corresponding time "t_1," which may be anywhere in the cycle, the voltage of the outer grid rises to about 70 volts, as shown in Fig. 5, as the 0.5 mf condenser C_1 is charged to that value by the potential divider R_4. The condenser discharges through the resistor R_2 in an exponential manner, but since the time constant is greater than 0.05 second, the voltage of the outer grid remains substantially constant as in Fig. 5 (*a*). With a shift of outer grid potential from 0 to +70 volts, the locus of the peaked wave *ab* in Fig. 4 shifts to the right and crosses into the "conducting" region at point "*c*." The pulse then delivered to the starting band ignites the mercury arc at the time "t_2" in Fig. 5, and conduction through the mercury-arc tube and welder transformer continues for the remainder of the half-cycle.[10] Since the cross over into the conducting region of Fig. 4 occurs at a well-defined point on the peaked wave, and, since the angle of lag, θ, between the negative peaked wave and the line voltage can be controlled by the "resistance-condenser" phase shifter consisting of R_{10} and C_4, it is clear that the starting pulse can be delivered to the band on T_1 at an accurately preassigned time measured with respect to the a.c. voltage applied to the tube T_1 and thus the fraction of the cycle during which it conducts can be controlled.

There are two methods of controlling the intensity of the welding heat using this circuit, one being by phase control, and the other through amplitude control by means of R_1 in the primary line. The condenser C_1 is discharged by the grid current when the strobotron becomes conducting, and as long as the switch S remains closed, it can charge up to only one-third its normal voltage because of the current drain through R_2. The

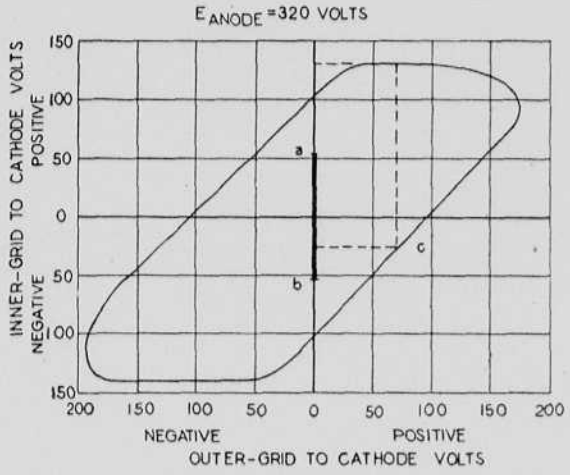

FIG. 4. Relation of grid voltages for starting the strobotron tube.

TABLE I. *Strobotron data.* Number of electrodes, 4: caesium covered cold cathode: gas, 1.5 cm, neon. Typical initial glow potentials in volts.

POSITIVE ELECTRODE	NEGATIVE ELECTRODE	NORMAL POTENTIAL DIFFERENCE	EXPECTED VARIATIONS
Outer grid	Inner grid	96	+15–5
Inner grid	Outer grid	110	+50–30
Anode	Outer grid	500	+50–100
Cathode	Inner grid	130	+15–10
Outer grid	Cathode	175	+25–15
Inner grid	Cathode	130	+10–10
Cathode	Outer grid	200	+40–60
Anode	Inner grid	600	+50–40
Average anode current (max.)			100 milliamperes
Instantaneous anode current (max.)			250 amperes
Average tube drop for arc			20 volts
Average tube drop for glow			80 volts

[9] The transformer we have used is designed to operate from 115 volts a.c. with a 5000 ohm resistor in series with the primary, and to deliver a peaked voltage of about 110 volts. If a different transformer is used, resistors R_7, R_8, and R_9 should be modified.

[10] Actually, conduction continues for a short time into the next negative half-cycle, due to the leakage inductance of the transformer.

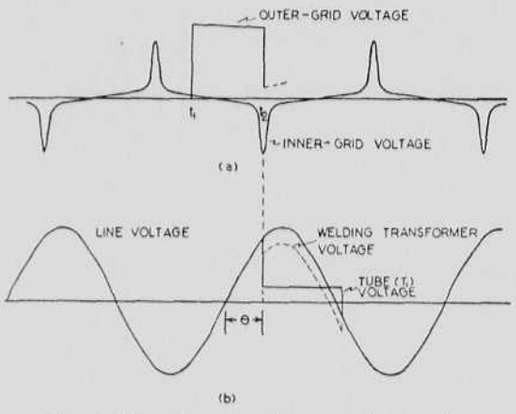

FIG. 5. Wave form of voltages in the circuit.

contact point on R_4 is adjusted so that the corresponding shift in outer grid voltage is insufficient to cause the locus of the peaked wave in Fig. 4 to cross into the conducting region, and therefore only one pulse is obtained each time the switch is closed. The anode voltage of the mercury arc tube T_1 must be more positive than a critical value of about 50 volts in order that an arc start when the external band is excited. The useful range of phase control is therefore from about 10° to 170°.

PRESSURE REQUIREMENTS FOR STRONG WELDS

A spot weld produced by a very high current over a short time has the advantage that the neighboring metal does not become hot. To force the high current through the transformer, it has been found suitable to operate the primary winding normally rated at 115 volts from the 230 volt line. Peak currents of 300 amperes occur in the primary line, thus it is necessary to use heavy wiring for low resistance.

With the intense local heating at the weld, higher than normal pressure is required to prevent vaporization of the material and to provide the requisite forging action. By means of a pendulum type tensile tester, we have measured the strength of about two hundred welds made between round nickel wires of the three sizes, 10, 35, and 50 mils in diameter, using various values of current and force. The results of these tests indicate that a force of 40 lb. is desirable to produce the best welds in the larger sizes of wire, but that for the smallest wire a force of 20 lb., together with a reduced current, is satisfactory.