HAROLD E. EDGERTON

PAPERS

MC 25

SERIES 3. LABORATORY NOTEBOOKS

NUMBER: T-4

DATED: 16 June 1933 – 9 November 1934

Edgerton Ex. 13

Massachusetts Institute of Technology

COMPUTATION BOOK

NAME	Number
HAROLD E. EDGERTON	T-4

Course

Used from June 16. 1933, to Nov. 9 1934.

Acl. 3041-M Witherell.

Harold. E. Edgerton
Mass. Inst. of tech.
Room 10-085
June 16, 1933.

June 15.

Went to Bellows Falls plant with Spencer and Buell.

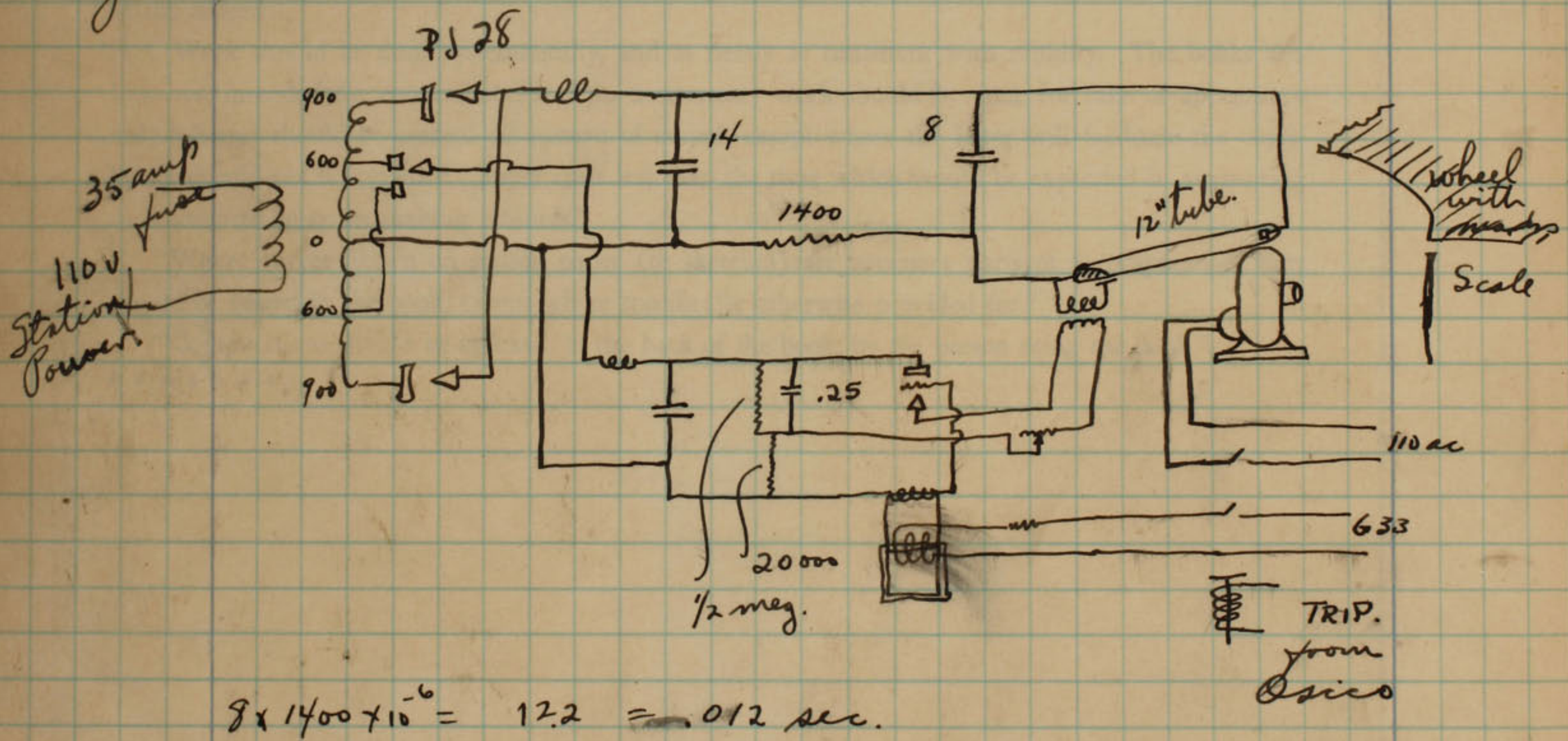
June 16.

Installed stroboscope in unit No. 1.

Power-angle test.

Test. No.	Volts	Angle	Amps	Amps, field	K.W.	P.f.
1	6950	127	425	350	0	—
	6950	113	710	360	7500	.84 lead
	6950	101	1300	420	15000	.96 lead

June 17.



$8 \times 1400 \times 10^{-6} = 11.2 = .012$ sec.

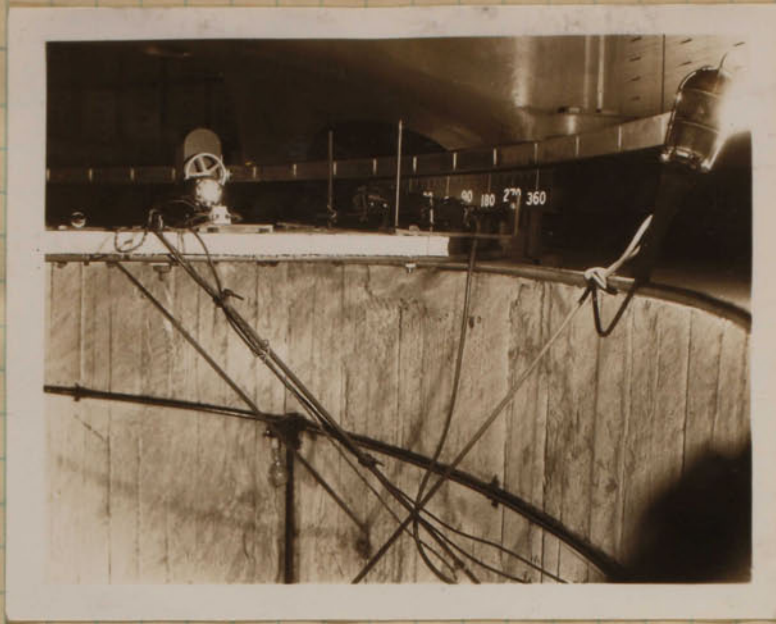
Circuit above is the one installed in the Bellows Falls plant of the N.E.P. Company. An automatic oscillograph (osciso) was also left in the plant to record watts, current, and voltage. It was set to run about 5 seconds as was the camera.

We returned to Boston on Sunday afternoon June 18.

Apparatus sent to Bellows Falls and loaned to the New England Power.

Stroboscope circuit in Box.
Bodine Synchronous motor and gears to drive the camera.
Two ring stands with clamps to hold tube holder.
Spare tubes
- 2 - (PJ-28) rectifier tubes.
- 1 - FG-17 thyratron
- 1 - UX 83 rectifier tube.
- 4 - 12" stroboscope tubes.

4 - 100 ft reels Dupont 16 mm N.H. Special Panchromatic film. (Spencer is going to replace this film with some that he is ordering.)

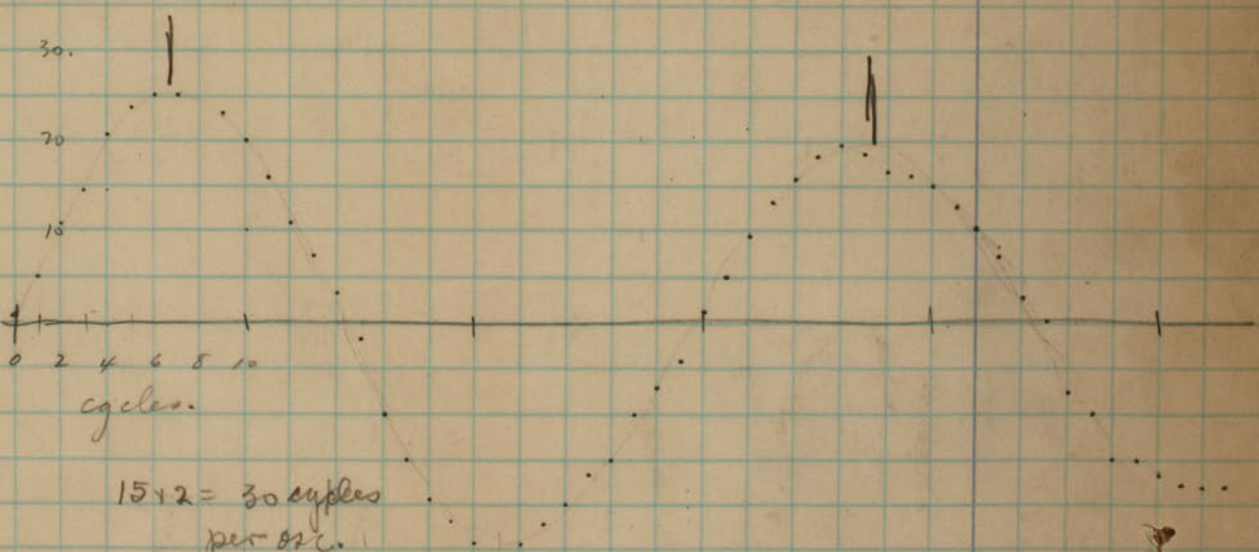


90 180 270 360

Data from the third synchronizing shot.

$$\frac{\begin{matrix}180\\127\end{matrix}}{53}$$

leg from zero

52?	1	38	15
48	5	41	12
42	11	43	10
39	14	46	7
32	21	51	2
30	23	53	0
28	25	—	—
28	25	61	-8
—	—	63	10
30	23	68	15
33	20	68	15
37	16	70	17
42	11	71	18
46	7	71	18
50	3	71	18
55	-2	69	16
72x	—	68	15
63	-10	76x	—
68	-15		
72	-19		
75	-22		
77	-24		
—	—		
77	-24		
75	-22		
73	-20		
70	-17		
68	15		
63	10		
60	7		
57	4		
52	+1		
48	5		
42	9		
40	13		
37	16		
35	18		
34	19		
35	18		
36	17		
36	17		



15 x 2 = 30 cycles per osc.

2 cyc. per second.

July 16 1933.

Spin of milk drops from films taken last saturday. Pressures 6#. Light frequency = 1020 per sec.

	diam. mm	cent. of noz. in cm.	diam noz. "	angle shift.	Speed. translation	R.P.S.
6#	7x3	37 40.5	10.4 cm " 1/2"	66°	171.5 inch/sec.	187.
	7x5	36.0 32.5	.3.5	60°	171.5	170
	7x5	44 40		42.°	196	119
	9x4	38.5 35.5		85	147	240
	6x4	34. 31.		50	147.	142

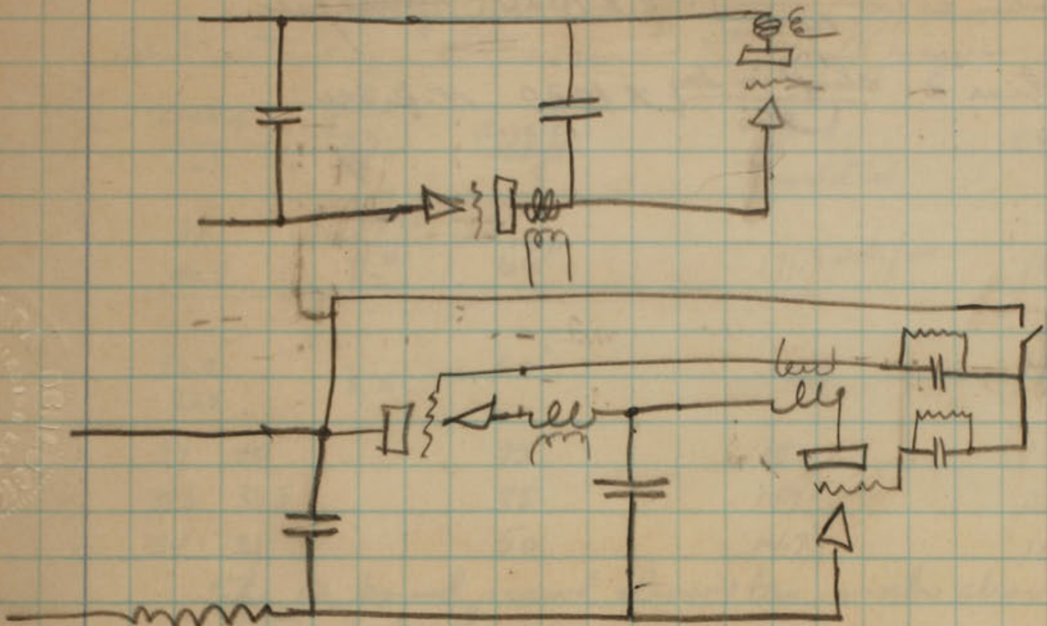
The 12 pound record shows too much change between pictures

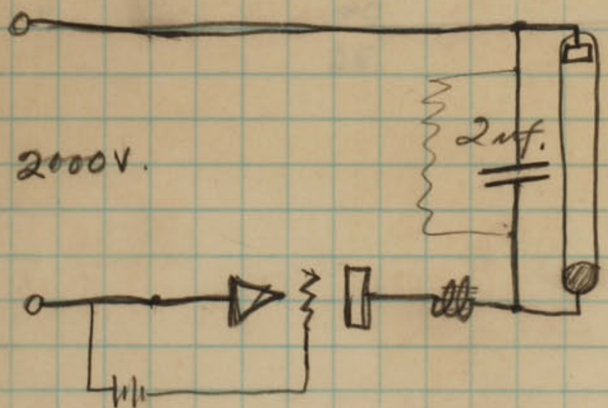
3#	7x6.	31.5 30.	1.5	40
	10x7	47. 44.5	1.5	43
	10x7 or 8	34. 33	1.	15
	10x "	"		40
				35

Speed in translation = $\left(\frac{\text{av. motion}}{10.4}\right) \times \frac{1}{2} \times 1020.$ inches/sec.

Speed of rotation = $\frac{\text{shift in deg}}{360} \times 1020$ r.p.sec.

July 19 1933.





$$I_{max} = \frac{E}{\sqrt{\frac{L}{C}}} \qquad 20 = \frac{\overset{100}{\cancel{2000}}}{\sqrt{\frac{L}{2\times10^{-6}}}} = \cancel{\sqrt{2}\times10^{-3}} =$$

$$L = \cancel{10{,}000}\ 20 \times 10^{-6}$$

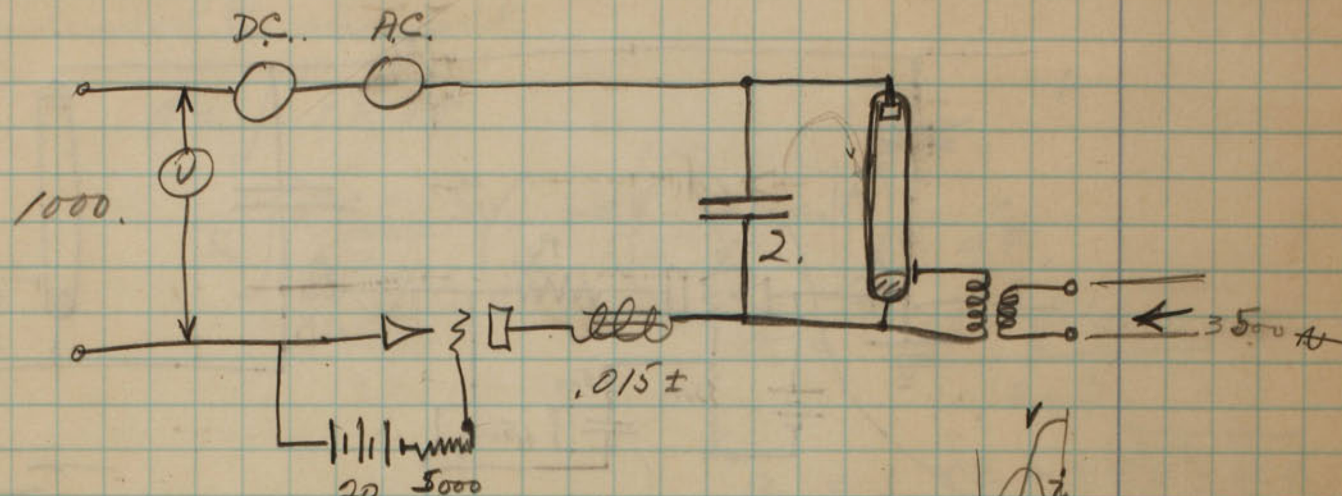
$$= .0141\ h$$

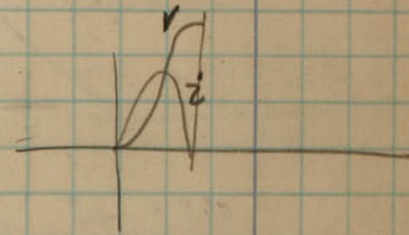
16
.024
14

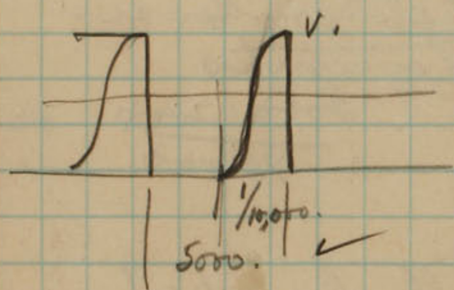
$$F = 2\pi\sqrt{LC} = 6.28\sqrt{.014\times2\times10^{-6}} = .16\times10^{-3}$$

$$\tfrac{1}{2}\ cyc. = .08\times10^{-3}$$

$$.00008$$

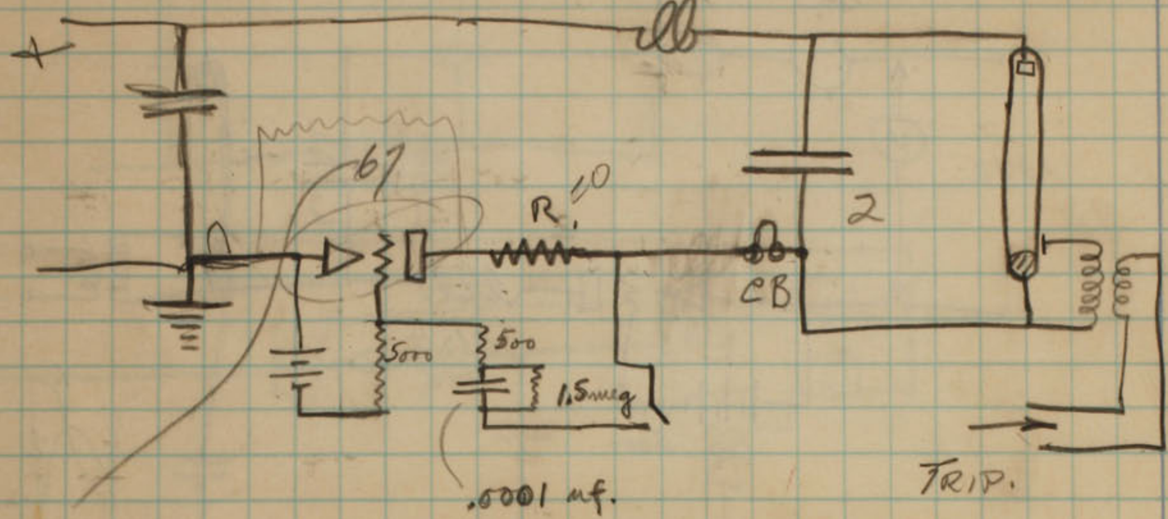






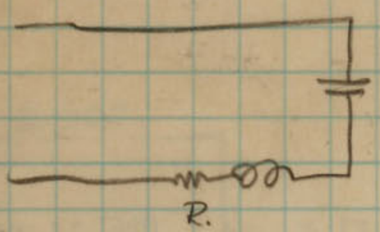
Mr. Brickett Lowell Textile Inst called for stroboscope.

United States Patent Office
Before the Examiner of Interferences
Edgerton vs. Miller - Interference 76771
<u>Edgerton Exhibit 13.</u>
Pages 8, 9, 10, 13, 14 & 15 of Edgerton Notebook T-4, July 19 & 20, 1933.
(6 pages, - page 9)
January 2, 1940.   Clara Schlosky
Notary Public



This thyratron trips when the main condenser discharges and causes short circuits

~~2000 2000~~ 40
~~X5000~~



Critically damped.

$$r = 2\sqrt{\frac{L}{C}}$$

$\sqrt{.007} = .08.2$

$$= 2\sqrt{\frac{.015}{2\times 1}} \times 10^{3}$$

$$= .16 \times 10^{3} = 160 \text{ ohms.}$$

$$\frac{1000v^{2}\ 2\times 10^{-6}}{2} = 1 \text{ joule}$$

5000 times per sec. = 5000 watts.

1000 volts 5 amps.

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January 2, 1940

Clara Schlosky
Notary Public

$\frac{r}{32}$

July 19 1933

Energy lost in resistance when condenser is charged.

$$P = \int i^2 R \, dt.$$

$$= \int_0^\infty \left(\frac{EC}{\sqrt{r^2C^2-4LC}}\right)^2 \left(\varepsilon^{-a_1 t} - \varepsilon^{-a_2 t}\right)^2 R \, dt.$$

$$a_1 = \frac{rc - \sqrt{r^2c^2-4LC}}{2LC}$$

$$a_2 = \frac{rc + \sqrt{r^2c^2-4LC}}{2LC}$$

$$= \left(\frac{E^2C^2R}{r^2C^2-4LC}\right)\int_0^\infty \left(\varepsilon^{-2a_1t} - 2\varepsilon^{-(a_1+a_2)t} + \varepsilon^{-2a_2t}\right) dt.$$

$$\int \varepsilon^{ax} dx = \frac{1}{a}\varepsilon^{ax}.$$

$$\therefore \left(\frac{-1}{2a_1}\varepsilon^{-2a_1t} + \frac{2}{(a_1+a_2)}\varepsilon^{-(a_1+a_2)t} + \frac{-1}{2a_2}\varepsilon^{-2a_2t}\right)\Bigg]_0^\infty$$

$$= \therefore \left(\frac{2}{(a_1+a_2)} - \frac{1}{2a_1} - \frac{1}{2a_2}\right) = \therefore \left[\frac{L2}{r} - \left(\frac{2a_2+2a_1}{4a_1a_2}\right)\right]$$

$$= \therefore \left(\frac{2}{\frac{2rC}{2LC}} - \frac{LC}{2\left(rc - \sqrt{r^2c^2-4LC}\right)} - \frac{LC}{2\left(rc + \sqrt{r^2c^2-4LC}\right)}\right)$$

~~$\therefore \frac{2L}{r} - \frac{2LC}{r^2C^2 - r^2C^2 - 4LC} = \frac{2L}{r} - \frac{1}{2}$~~

$$LC\left[\frac{rc + \sqrt{r^2c^2-4LC} + rc - \sqrt{r^2c^2-4LC}}{r^2c^2 - r^2c^2 - 4LC}\right]$$

$$\frac{2rc^2L}{4LC} = \frac{rc}{2}.$$

$$\therefore \frac{E^2C^2R}{r^2c^2-4LC}\left(\frac{L2}{r} - \frac{rc}{2}\right)$$

Power lost in charging resistor

$$P = \frac{E^2C^2R}{R^2C^2 + 4LC}\left(\frac{L}{R} - \frac{RC}{2}\right).$$

special cases when $R = 0$ $P = 0$. ✓

when $L = 0$ $P = -\frac{E^2C}{2}$ ✓

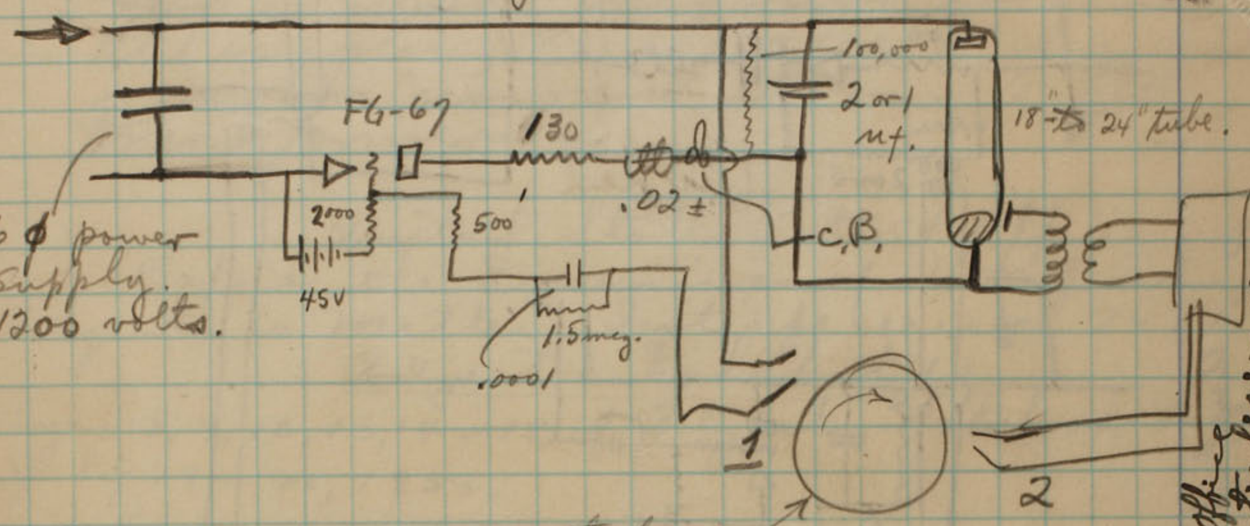
(Energy lost in R = energy stored in condenser.

Critically damped case.

$$R = 2\sqrt{\frac{L}{C}}$$

July 20 1933
H. E. Edgerton.

Spent all day experimenting with circuit shown on page 10 of this book.

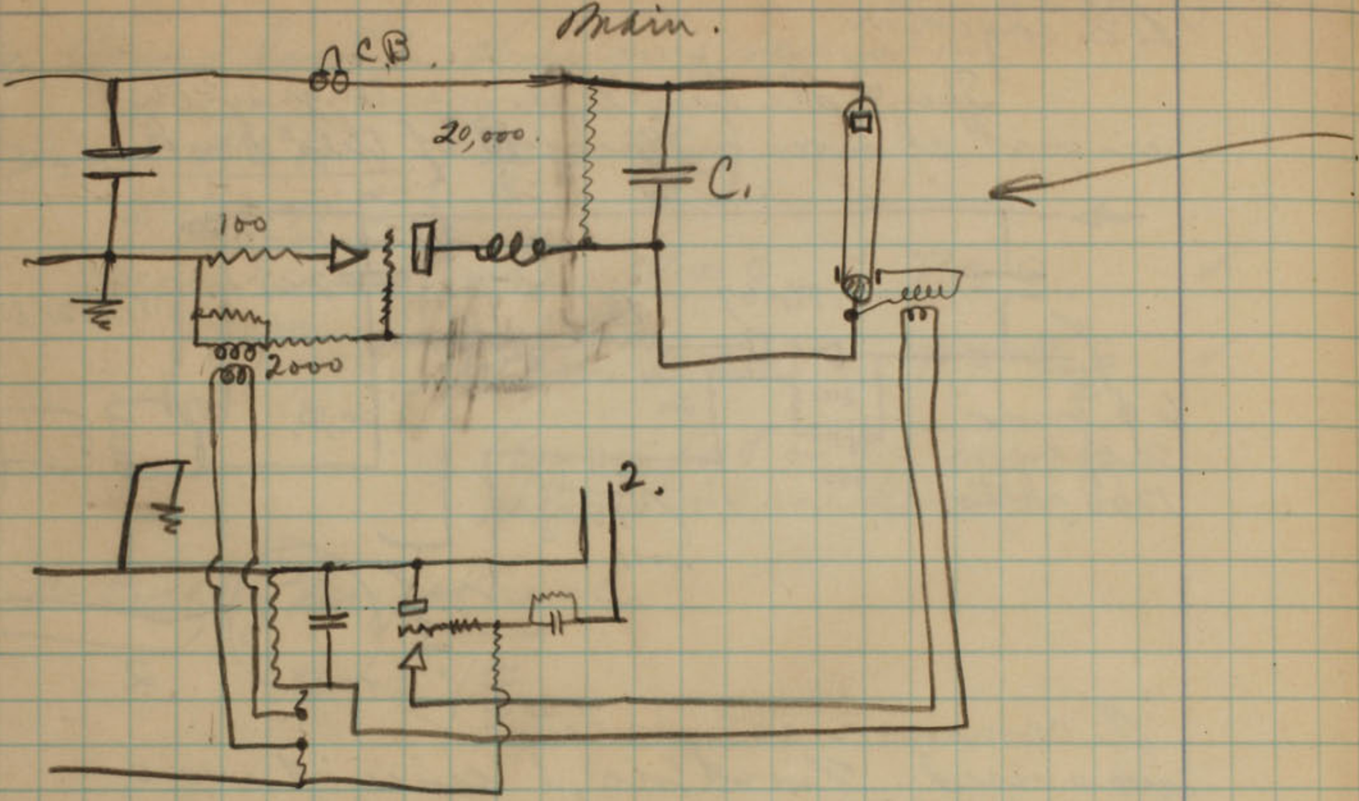


A common commutator was used. First no 1 circuit was tripped which caused a sudden surge to fill up the flashing condenser. Then no 2 circuit was tripped which put a spark on the ~~tube~~ stroboscope tube and caused it to discharge the condenser.

This circuit kicks out the C.B. on any provocation. Reducing the grid resistor of the 67 helped to stabilize the outfit.

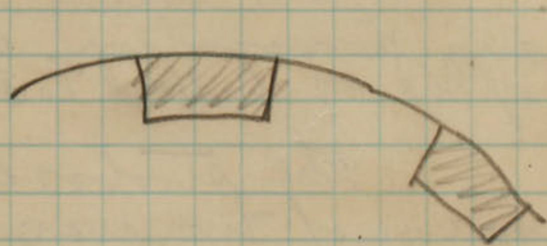
The stroboscope tube discharges in one of two ways. 1. It acts as a rectifier discharging a condenser through an inductance or 2. It conducts both directions. In the first case the voltage on the condenser is reversed so that the next surge through the thyratron puts a larger + voltage on the condenser.

A two ohm or even a one ohm resistor in series with the stroboscope tube damped the oscillations sufficiently to prevent a reversal and backfiring.



Spark.

The segments might be large so that the No 1 circuit is made on the break and the No 2 circuit is made on the make.



$2 \times 10^{-6} \times 400 = 8 \times 10^{-4}$

.0008

$\frac{1}{15000} = 67$

Tomorrow we are going to try the push-pull scheme of operating the lamps.

The charging 6J has its grid self biased when the condenser is charged. At the moment of discharge the grid is made negative because of the coupling & the spark charging ~~resistor~~. current through a the transformer.

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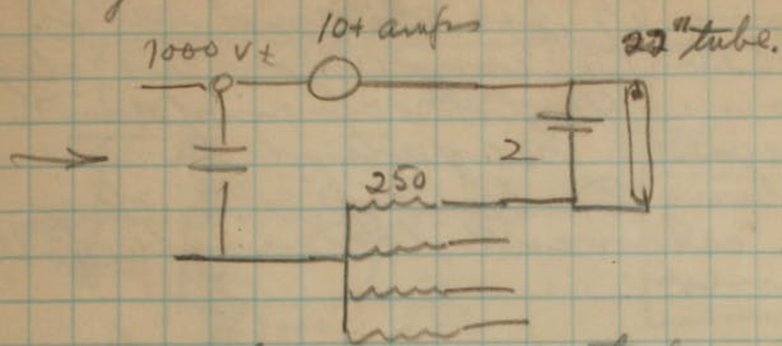
July 23 1933
H E Edgerton

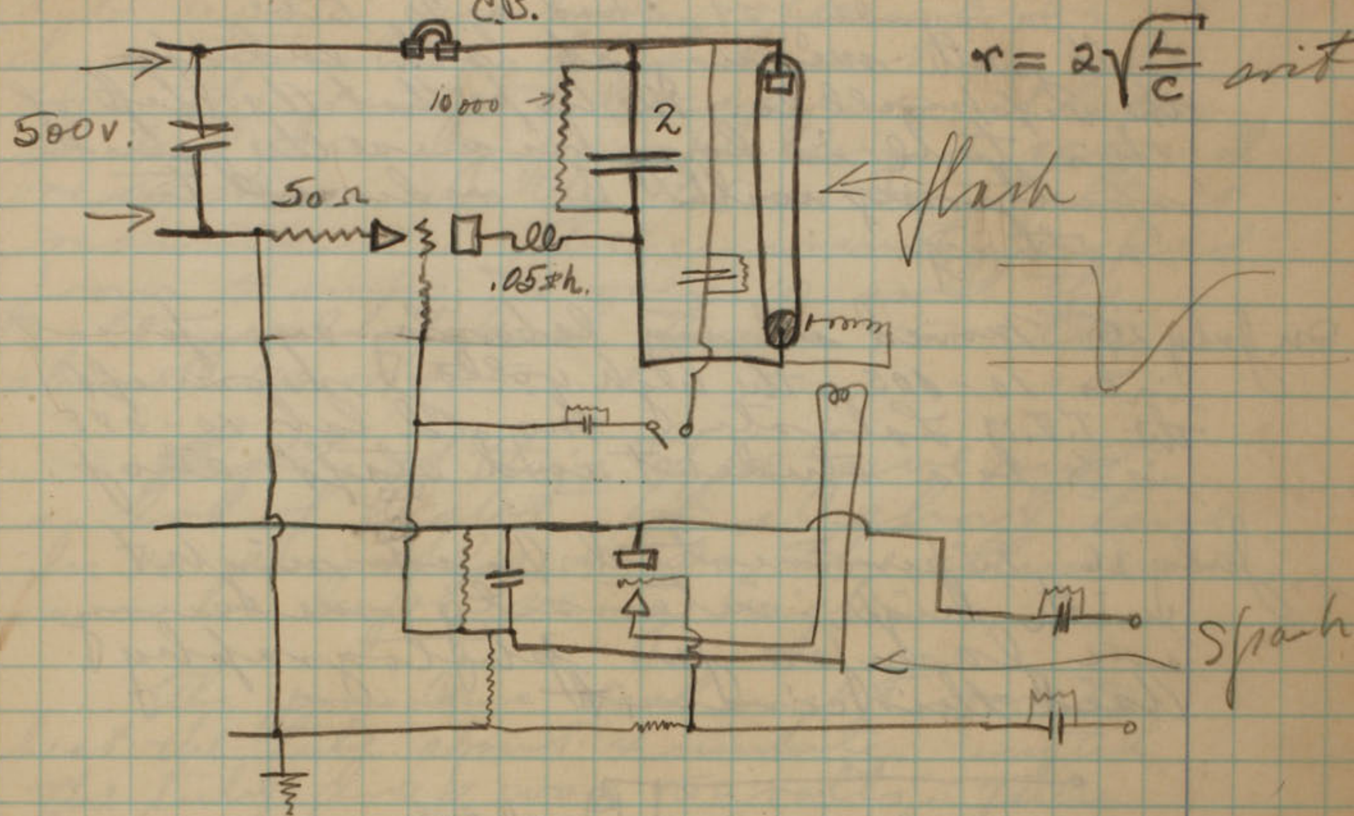


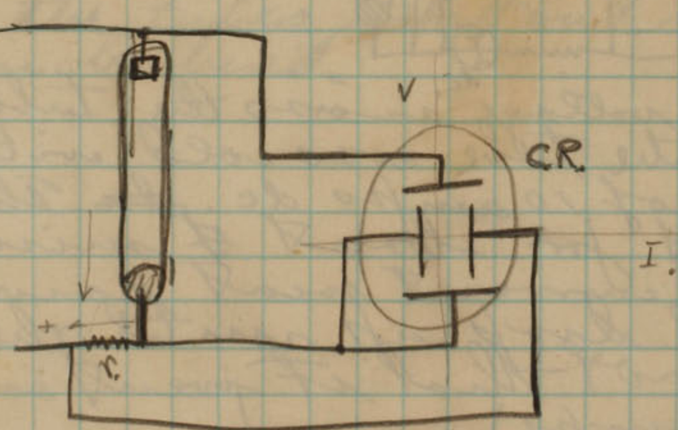
Four large 22 inch tubes do not work satisfactorily in this circuit at 1500 ~.

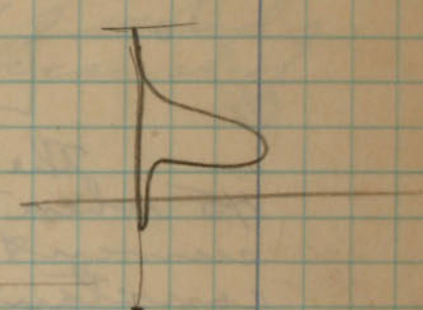
With short tubes 12" long and with 400 ohms in the charging circuit the above works fair at 1500 ~. 7½ amps flows at first but soon goes down to about 5 or 6 amps as the tubes heat up.

$RC = 400 \times 2 \times 10^{-6} = .0008$ sec.

$r = 2\sqrt{\frac{L}{C}}$ crit damped





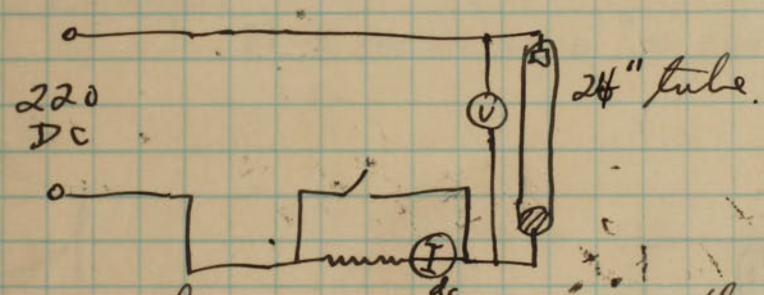


July 26 1932.
H. E. Edgerton.

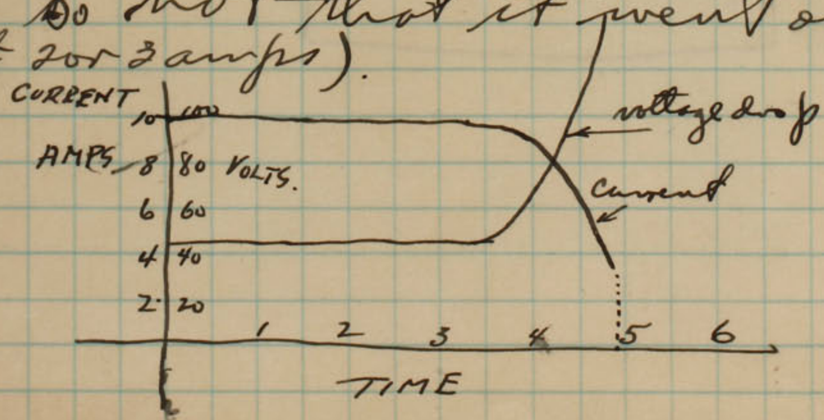
On monday 24, I had a 20" tube built with mercury at both ends for the Pepperell co. We hope that the life of this tube is long because the anode sputtering will be reduced to nothing.

On July 25. Moved all my laboratory equipment into 10-003, the high voltage room off the T.E.M. Laboratory. My old lab 10-088 is to be a student and staff shop.

July 26. Experimented last night with high intensity mercury arc lamps for photography. Used this circuit



The voltage across the tube was 45 when the tube was cold with a current of 10 amps dc. This held constant for about 4 minutes then the current went down and the tube drop up until the lamp got so hot that it went out (at 2 or 3 amps).



I tried to short the resistance with a switch when the lamp had a drop of 150 volts, to see if the tube had a positive volt-ampere characteristic. It did not as it blew the circuit breakers. I later checked this by paralleling a second resistor with the ~~same~~ ballast resistance. The current jumped from 4 amps to over 10 and the voltage dropped from 150 to about 110 or 125.

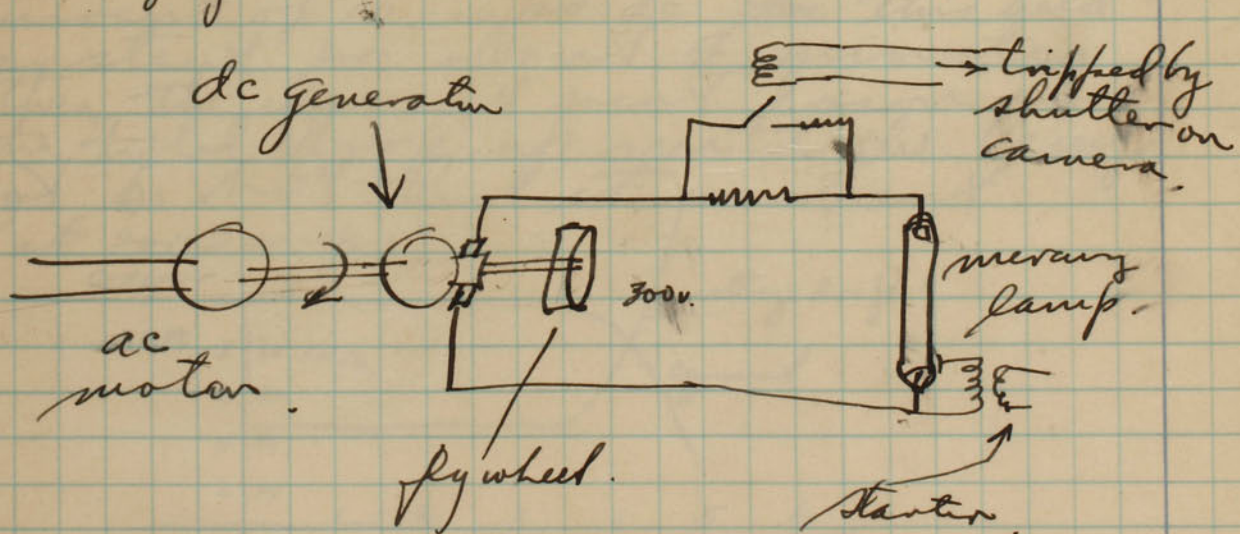
Lights of this type give out a lot of light for a short time. In 10 seconds or so the illumination can be kept very high.

The procedure last night was to heat the tube about 4 minutes until the tube drop was 150 volts. Then the switch was closed and the 10+ amps gave ~~a~~ considerably more light for a duration of about 7 seconds before the tubes went out because of too much heat.

July 26 1933
H. E. Edgerton.

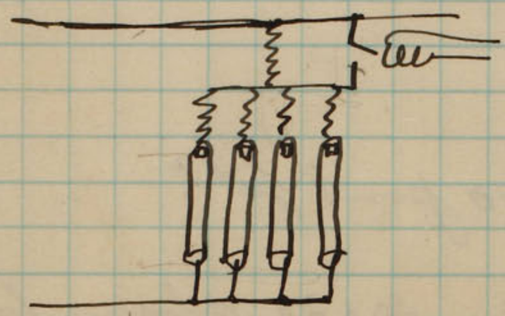
Flash Photographic Light Source

Electrical energy can be converted into mechanical kinetic energy in a rotating machine which may have a flywheel for additional inertia. Energy stored in this manner should be very convenient for taking flash light photographs in studios etc. Mercury arc lamps of the type described could be run from the generator at normal intensity to warm them up. After a reduced resistance or an increase in the field current of the generator would increase the intensity many fold. The power drain would not be large because the m.g. set would supply the peak energy due to its (inertia) stored kinetic energy.



The ac motor can be designed ~~to~~ so that it will not draw more than say 1000 watts from the line. The outfit can thereby be put on any ordinary lighting circuit.

More lamps can be used in parallel by putting a ballast resistor for each.



The scheme for storing energy in a rotating mass should also be very useful for X ray work. The M.G. set would store up the energy for the sudden pulses that are required for flash X rays.

The idea may also be useful in spot welding and in other applications.

Shown and explained to me July 26th 1933
Kenneth J. Germeshausen
D H Wilkins.

Discussed with Hugh Spencer Apr. 16. He said to come out to see [illegible].

July 26 1933.
~~Th~~ Edgerton

Stored energy in a rotating mass.

$$W = \frac{J_m \omega^2}{2} \text{ foot pounds} \qquad J_m = \text{pound(grav.) feet}^2$$

ω = radians / sec.

Let $w = 50$ pounds.
$K = 6''$

$$J_m = \frac{50}{32.2} \times 6 = 10 \text{ pound feet}^2.$$

5

1800 r.p.m = 30 rps = 30 × 2π radians / sec.

$$W = 2\pi 30 \times 10^2 = 20,000 \text{ foot pounds.}$$

Energy in the spark outfit,

$$W = \frac{CE^2}{2} = \frac{3 \times 10^{-6} \times 16,000 \;\; 16,000}{2}$$

24
16
16.4
24
404

= 404 Joules

5000 Joules × .7376 = foot pounds.
= 297 ft pounds.

The above calculations show that it will be relatively easy to store sufficient energy in a rotating mass to get good photographs from mercury lamps.

Energy in 25% speed drop.

$$W = \frac{J_m \omega^2 (1^2 - .75^2)}{2}$$

.475

.75 = 1000
.525
.475

July 27.

Took some spark photographs (24) of gap cavitation around an air foil in the ~~casa~~ Safe Harbor cavitation apparatus in the M.E. Lab. Ernst Spanhake, Venard, and two others are working on this problem this summer.

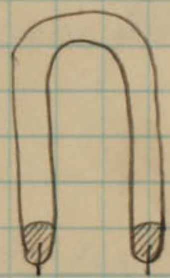
July 28.

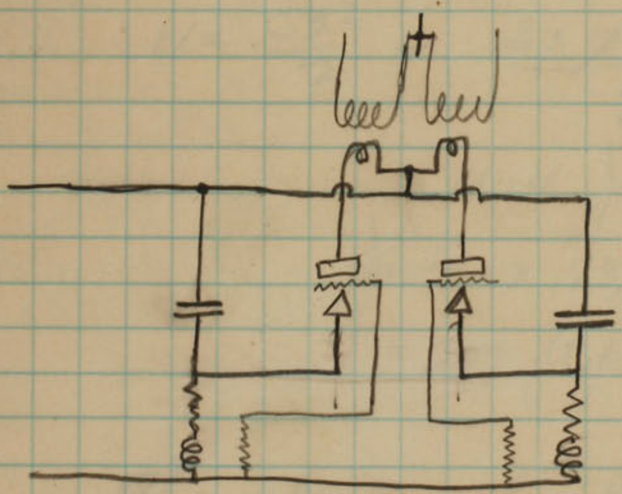
Saw Sargent Holmes about the army search light.

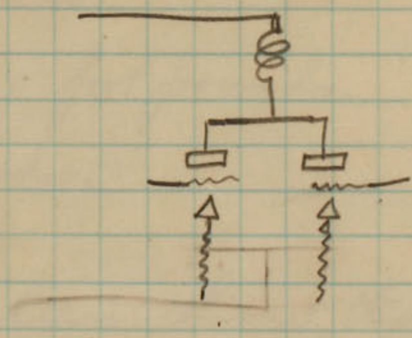
Experimented with high speed movie circuits. The spark coil oscillations are apparently responsible for the entire trouble of hold over in our present circuits.

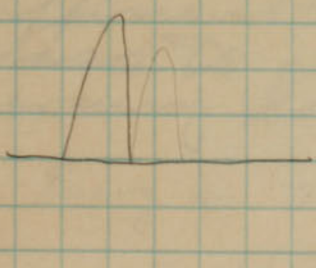
July 30, 1933.

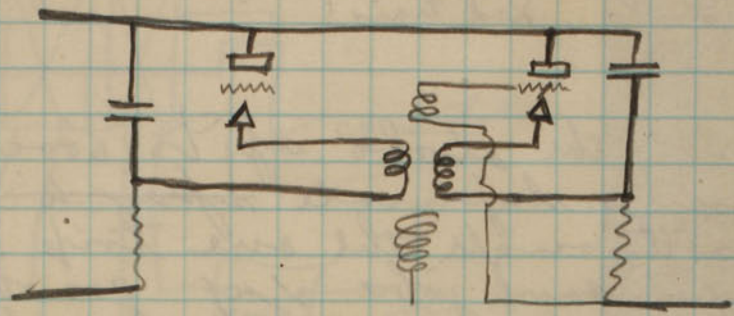
Took movies at 3000 per second. They were ~~slightly~~ jumpy probably because of brush trouble.

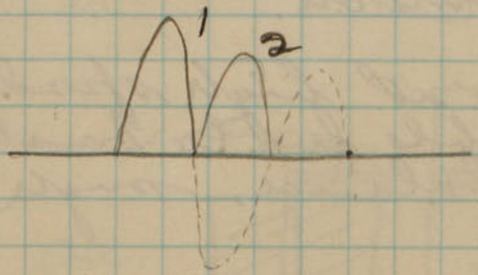


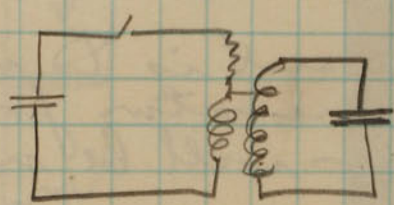









1
2



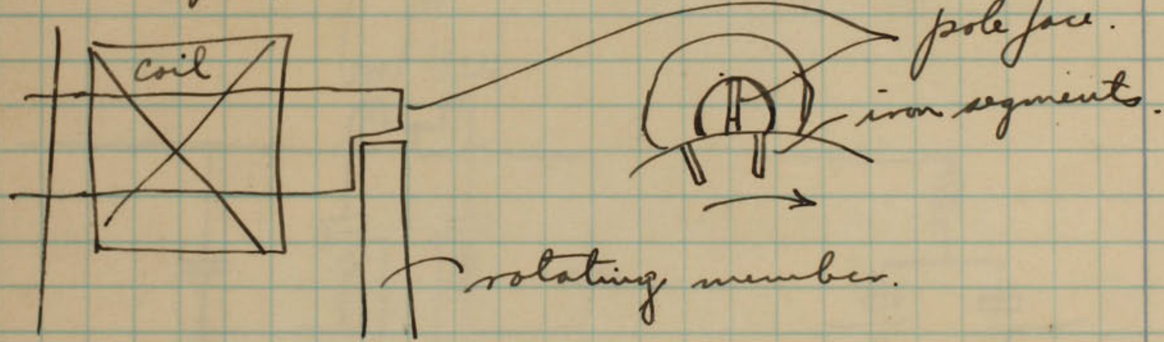
Aug 10, 1933

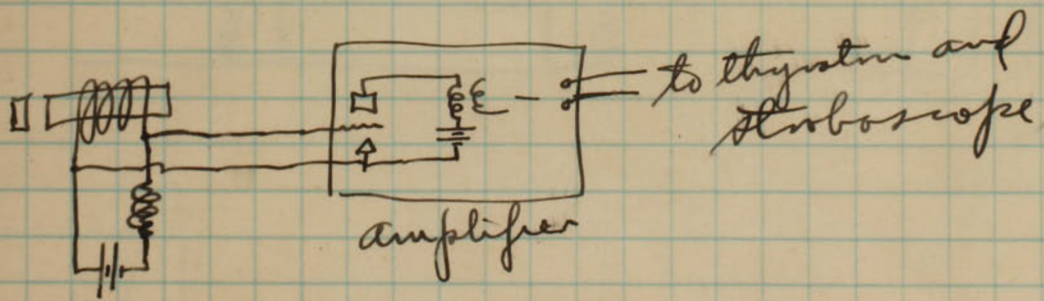
A boy arrived 11:45 yesterday at the Wyman house! 7 1/2 pounds, Red hair!

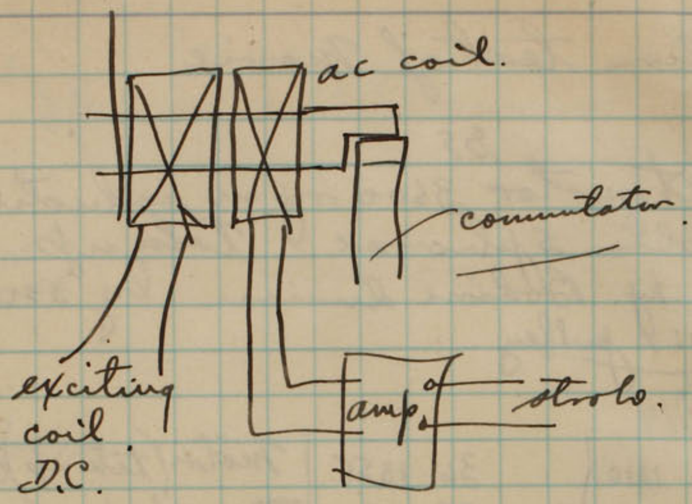
Germs got the strobo up to 6000 yesterday using duplicate ~~spark~~ thyratrons through the one trip transformer. Look fine for some jobs. 1 µf 200 ohms 1200 v dc. to main condenser. One lamp. Both 24" tube and 1 tube work o.k.

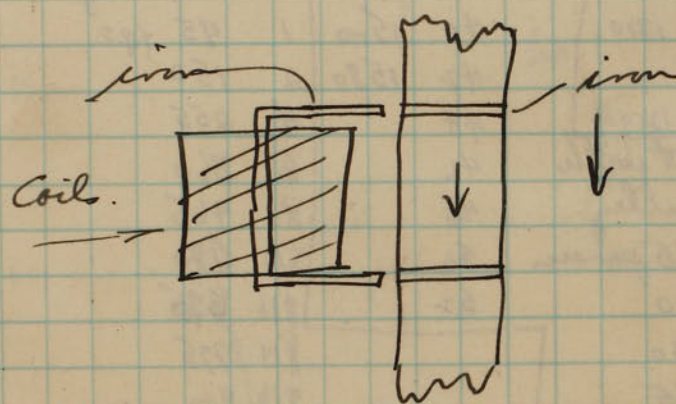
We get into trouble at high speeds with commutator trouble due to brush jitter caused by unbalance, rough spots, etc.

One way out is to use a reluctance generator for timing. A good amplifier will be needed.









6000/sec
Stearine through
pressure
nozzle.

Posted in
Sept 13 1934
H.E.E.

Aug 29, 1933. H. E. Edgerton.

Acceleration test of Movie Camera.

3 phase 220 volt G.E. motor 3600 rpm induction driven by 330 volts 3 phase. Take up motor 110 v. 1/30 hp. Bodine driven by 330 volts.

1:1 pulley.

Film no. 1.

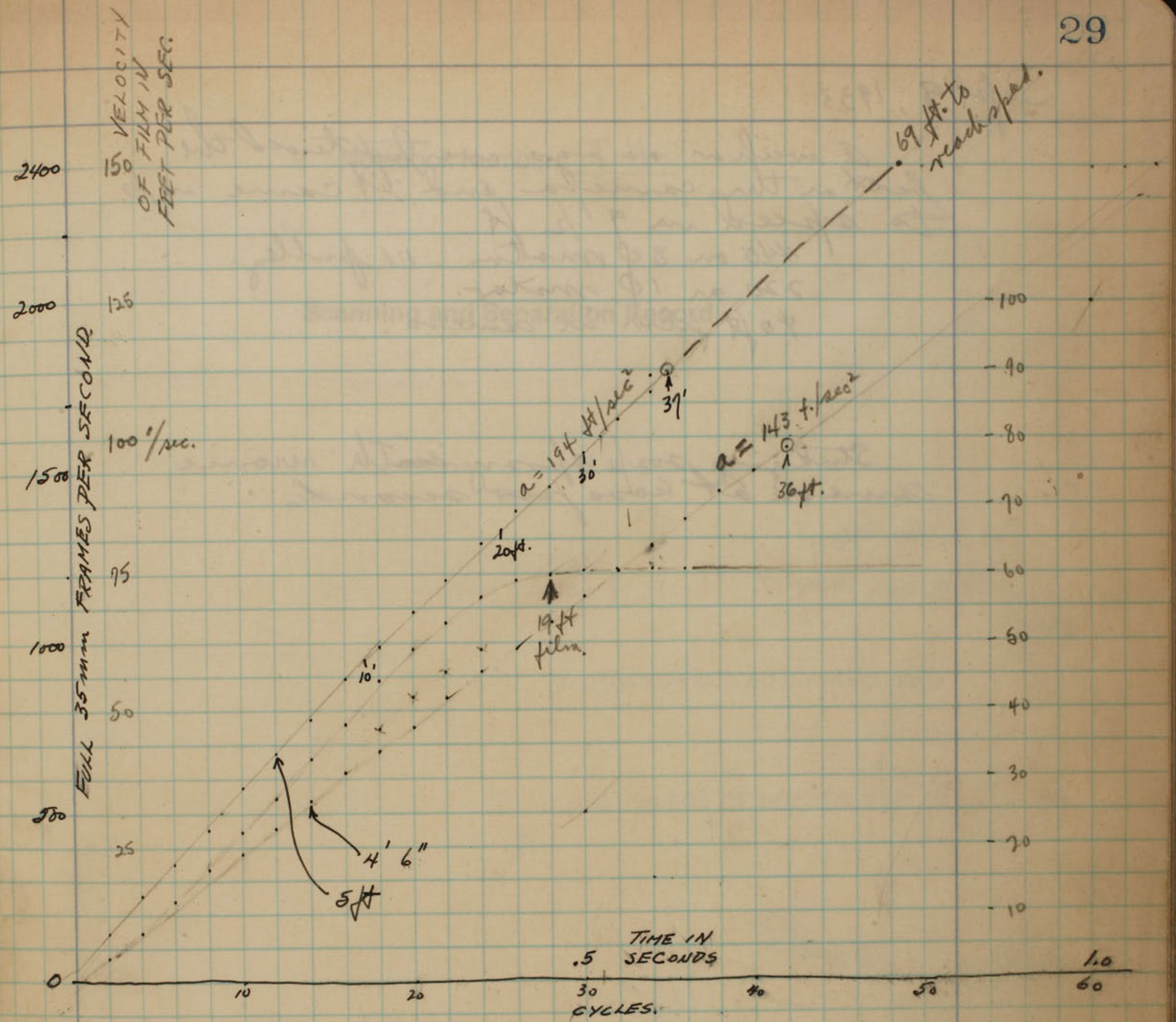
TIME. 1/60 sec.	f.p.s.	
1	?	
2	75 per sec.	
3.	120.	
4.	150	
5.	210	
6.	230.	
7.	300	
8.	330	
9.	380.	1' 10½"
10.	450	
11.	480	
12	540	
13.	600	
14.	660	
15.	690	
16	760	
17	825.	
18	890	
19	940	
20.	980	
21	1030	
22	1060	
23	1110	
24	1130	
25	1170	
26	1180	
27	1190	
28	1200	19'
29	1205	
30	1210	
31	1210+	
32	1210+	
33	1210	
34		
35	1210.	
}	1210.	

Same but with 2:1 pulley.

TIME SEC.		
1.	45 per sec.	
2.	90	
3.	130	
4.	165	
5.	210	
6.	240	
7	285	
8.	320	
9.	360	
10.	380	
11.	420	
12.	465	
13.	500	
14.	535	4' 6"
15	—	Film cut.
16.	615	
17	650	
18	685	
20	760	
22	835	
24	910	
26	985	
28	1060	
30	1130	
32	1205	
34	1280	
36	1355	
38	1430	
40	1500	
42	1580	
44		
46		
48		
50		
52		

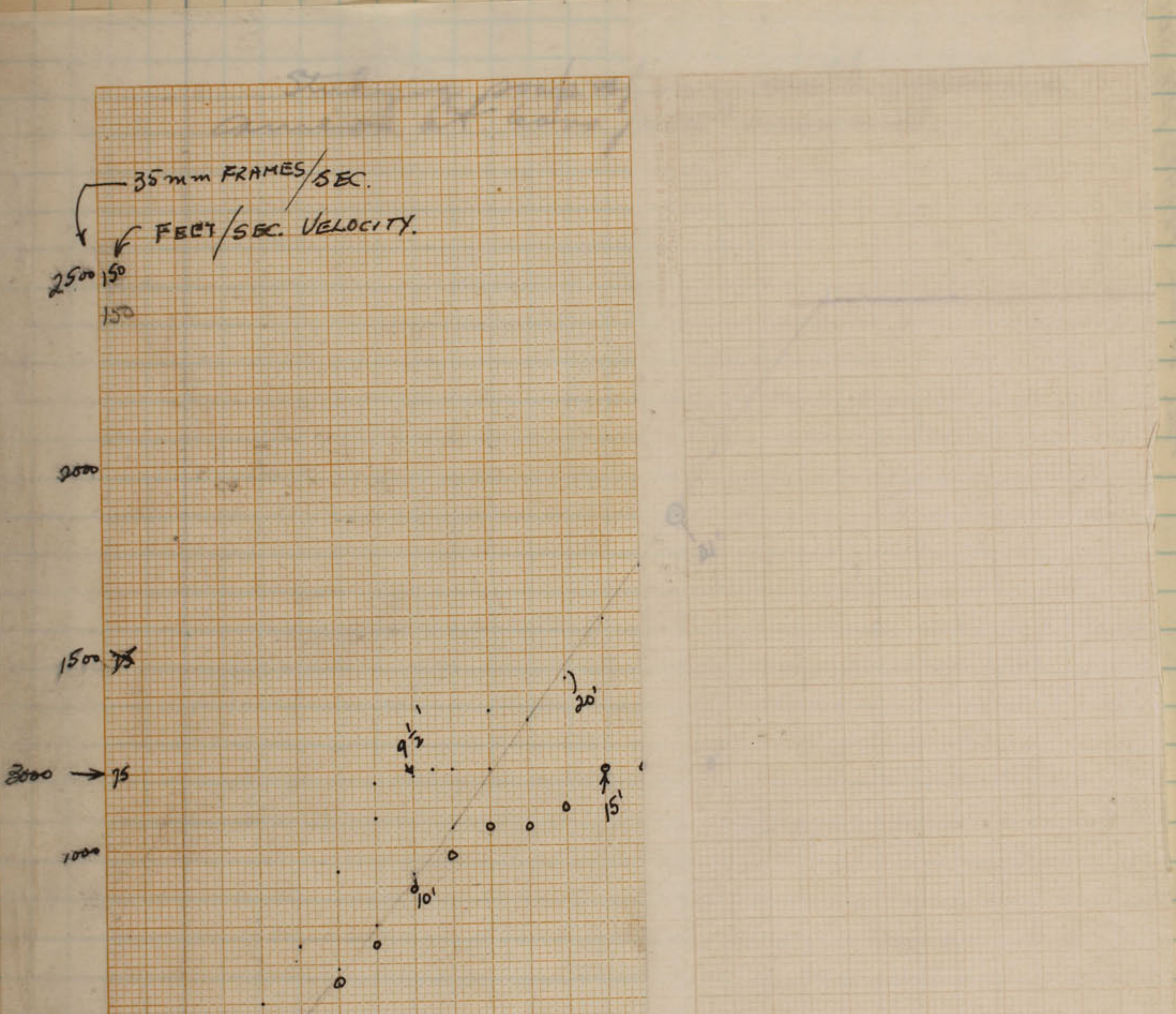
Motor (take up) changed to a 1/15 hp.

1	85 f.p.s.	
2	150	
4	255	
6	360	
8	465	
10	580	
12	675	
14	775	
16	900	950 10 ft.
18	980	
20.	1090	
22	1180	
24	1280	1325 20 ft.
26	1380	
28	1450	
30	1560	
32	1660	30 ft ~~1785~~
34	1740	
35	1785	

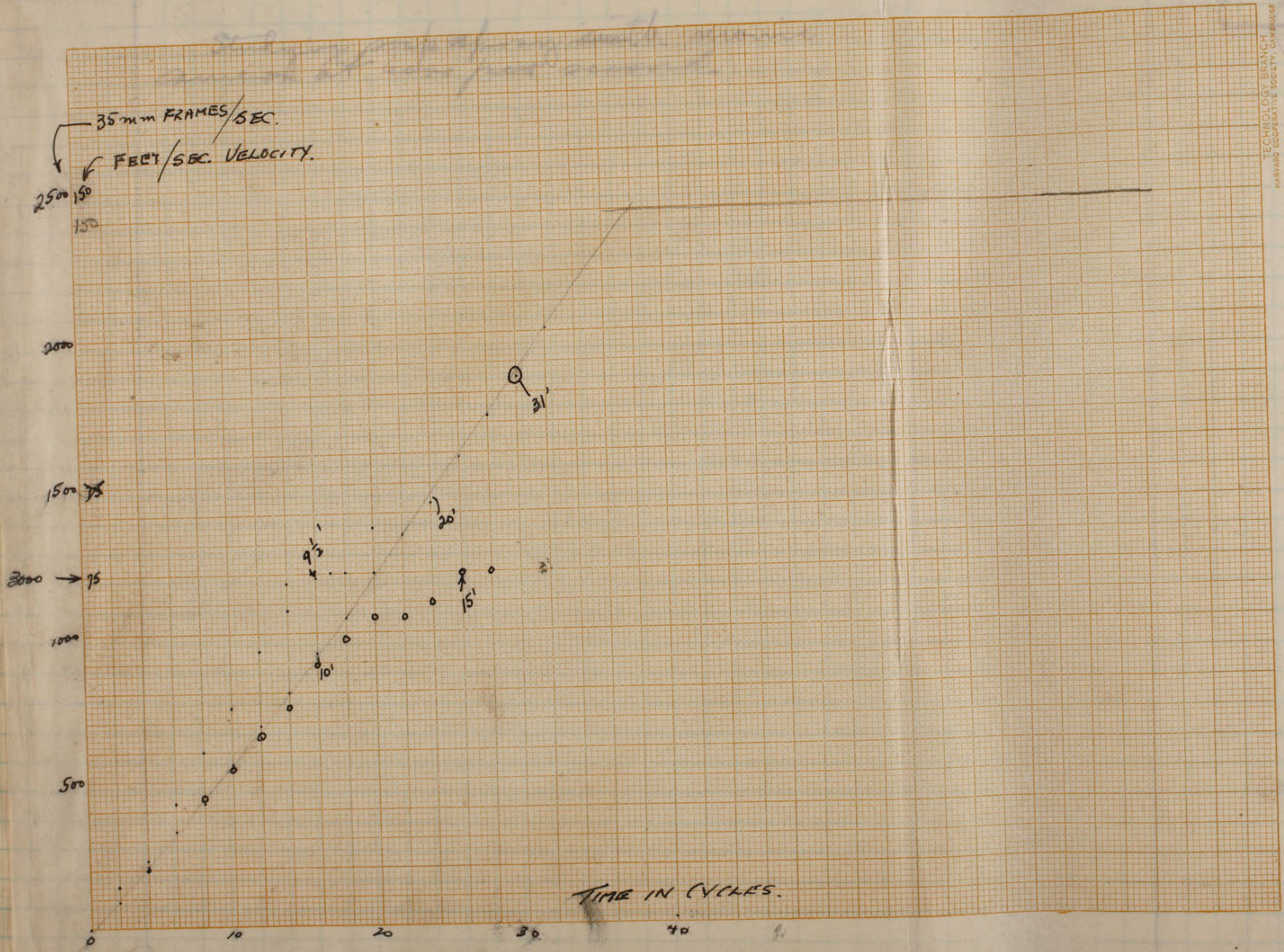

2400
2000
1500
1000
500
0
150
125
100 '/sec.
75
50
25
VELOCITY OF FILM IN FEET PER SEC.
FULL 35mm FRAMES PER SECOND
69 ft. to reach speed.
a = 194 ft/sec²
a = 143 f./sec²
37'
36 ft.
30'
20 ft.
10'
19 ft film.
4' 6"
5 ft
100
90
80
70
60
50
40
30
20
10
TIME IN SECONDS
.5
1.0
10
20
30
40
50
60
CYCLES.

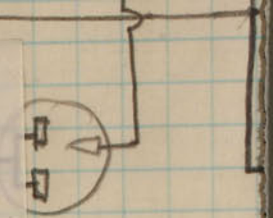
Sept. 9, 1933

a week or so ago we tightened the belt on the camera and it came up to speed in 9 1/2 ft.
440 on 3 ϕ motor 1:1 pulley.
220 on 1 ϕ motor.
40 ft film in camera.



40 ft film in camera.





.001.

Notebook Number: T-4

Scanning and Separation Record

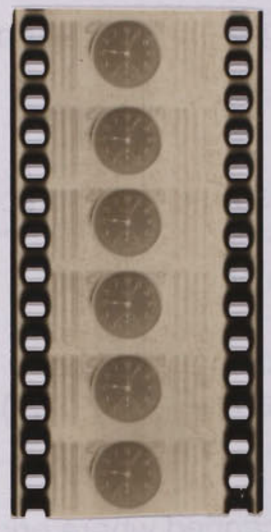
1 unmounted photograph(s)

____negative strip(s)

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

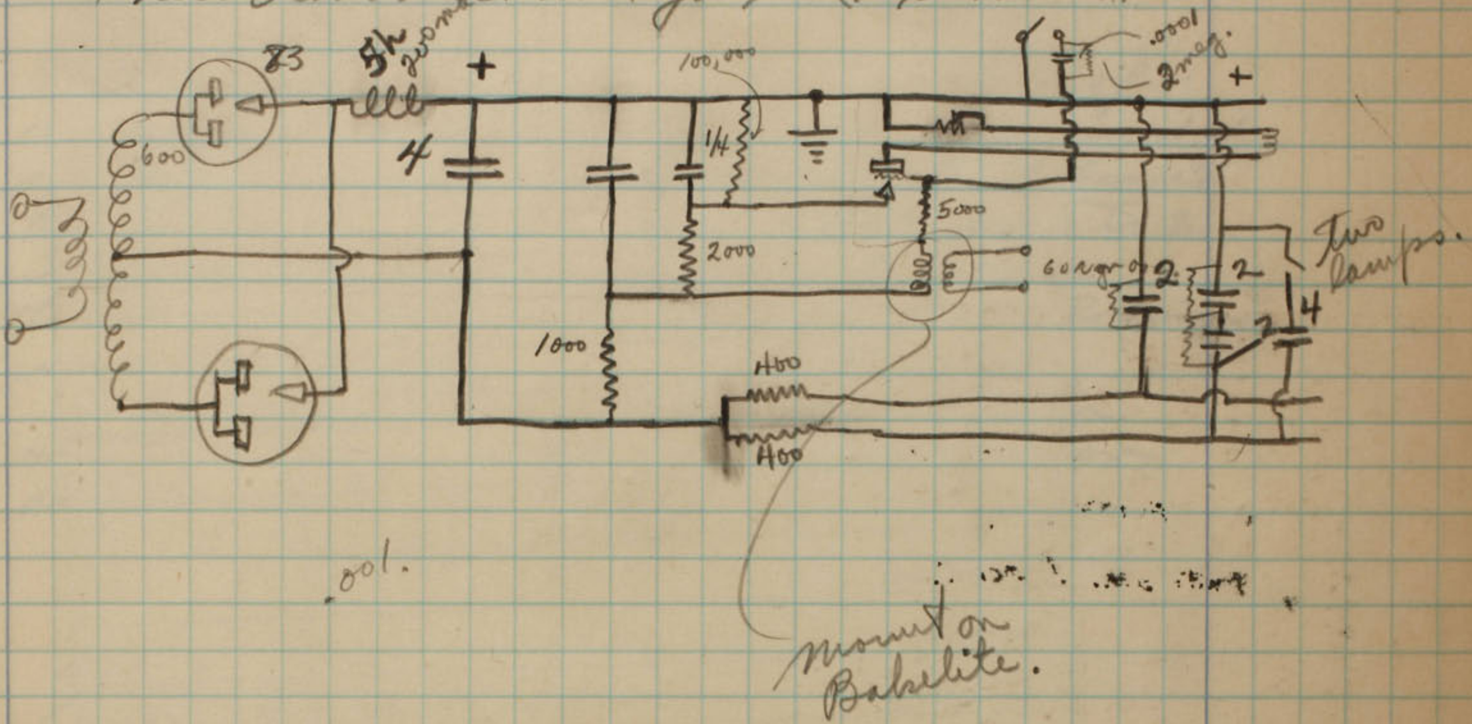
was/were scanned where originally located between page 30 and 31.

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



Sept 14 1933.

new Strobo circuit for G.R. to build.



.001.

245 20m 6-33 W

BASKET NO. 490 Mr Robinson

Expt'al Soap Gels

By Camb. Laboratory No. 573

Reported 9/19/33 Product

Rec'd from Mr. Robinson Plant

No.

Tested by FR Date Prod.

Kind	Experimental Soap Gels		
Name and Marks			
Date Received	9/18/33		
Sample		% water (Loss at 105°C)	% solids
Rinso Kettle Soap (9/14)	golf ball	28.25	golf ball 71.75
Sol'n Crutcher	9 out picture	93.28	9 out picture 6.72
5% Sol'n		94.77	5 - 5.23
15% Sol'n		81.38	15 - 18.62
25% Sol'n		69.15	25 - 30.85

Copy to:

Mr. Robinson (490)

A R Church
Chief Chemist

Sept 22, 1933.

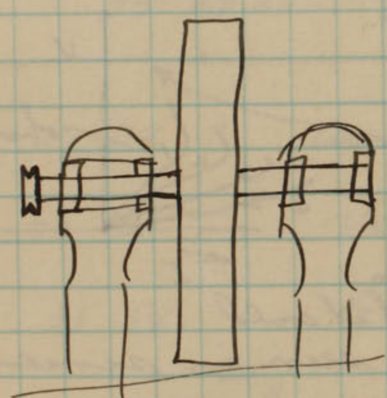
H. E. Edgerton.

The film (movie) showing the formation of round and hollow particles ~~of~~ by means of spray nozzles is nearly completed. I showed the parts on stearine and dilute soap to Mr. Stevenson (of A. D. Little) and Mr. Bodman this morning. Maxwell, Squires, Pease, Robinson were there also.

The remaining titles were taken over to the General Film lab. about noon and they will be ready tomorrow.

High speed camera.

Air suction to hold film on the drum.



3 ft cir.

6000.

30000 pict/sec.

80 pict/ft.

$\frac{30,000}{80}$ 375.0 ~~cf.~~ ft/sec.

$\frac{375.}{3} = 125$ r.p.s.

7500 r.p.m.

Oct 24, 1933.

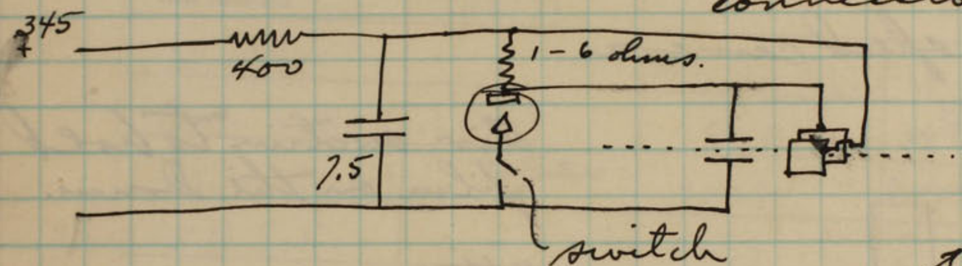
Discussed plans for High-speed camera with Wilkins and Mr. Richmond of the General Radio company.

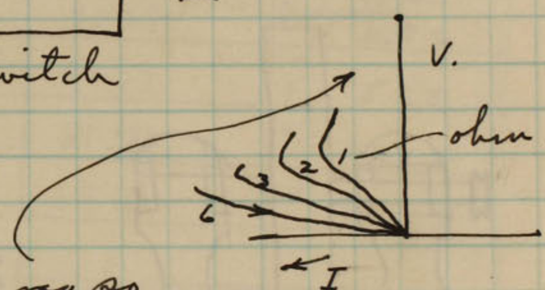
Oct 25 1933
H E Edgerton.

Experiments with hot-cathode Stroboscope tube.

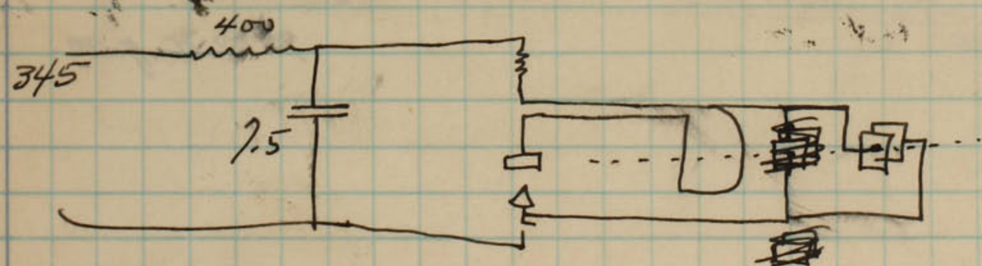
Experimental tubes from Hygrade which contain ~~[illegible]~~ 2 5 volt 5 amp filament were tested. They had a nickle cylinder around the filament.

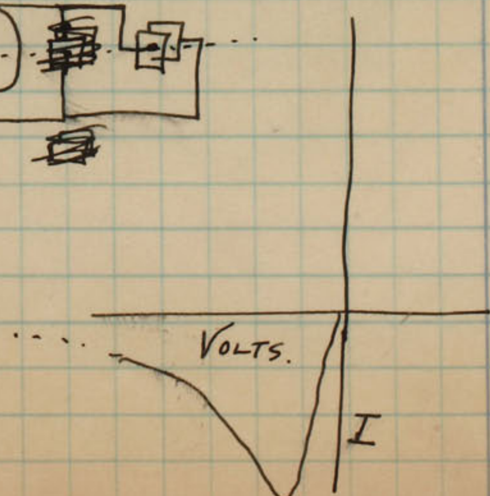
Cathode Ray osc. connections





ray so dim that it could not be seen on screen.





Photographs taken from the second setup on 35 mm movie NH Super pan Dupont film. 1/2 sec exposure approx.

Frames.	Resistance in series with discharge	Volts on filament.
1 2	1 ohm.	5 volts.
		~~5~~
3 4	(↓)	~~3.9~~ 4
5 6		~~4.1~~ 3.9
7 8		~~4.4~~ 4.1
~~8 9~~ 9.10		4.4
~~10 11~~ 11 12		5
~~12 13~~ 13 14	6	5
~~14 15~~ 15 16	3	(↓)
~~16 17~~ 17 18	2	
19 20	1	
21 22	.5	
23 24 25	0	

26 - 27 - 28 Current axis zero line.

29 30 31 Verticle calib 115 v 60 ac

32 33 34 Hor calib 115v. ac 60 ~.

Life test Oct 27 Oct 28 6 hours 345V ~~7~~.5 mf. 1 ohm

Oct. 28, 1933 Film test.
Edgerton
Eaton.

A chart prepared by Eaton was photographed to show the resolving power and the sensitivity of different kinds of motion picture film.

Experiment No 1.
15 ft of sound recording positive
5 ft of Dupont positive.

Four 12" strobo tubes
2 uf capacity on each
400 ohms charging resistor for each
10 KW power supply.
frequency 480 per second.
Warming time 5 seconds.

Camera lens f 1.4 30" to front of lens.

Center of lights about 8" from center of chart. White card reflector above aluminum reflector on opposite side.

Experiment 2.
10 ft of Dupont positive.
Ditto above but lamps cold to start.

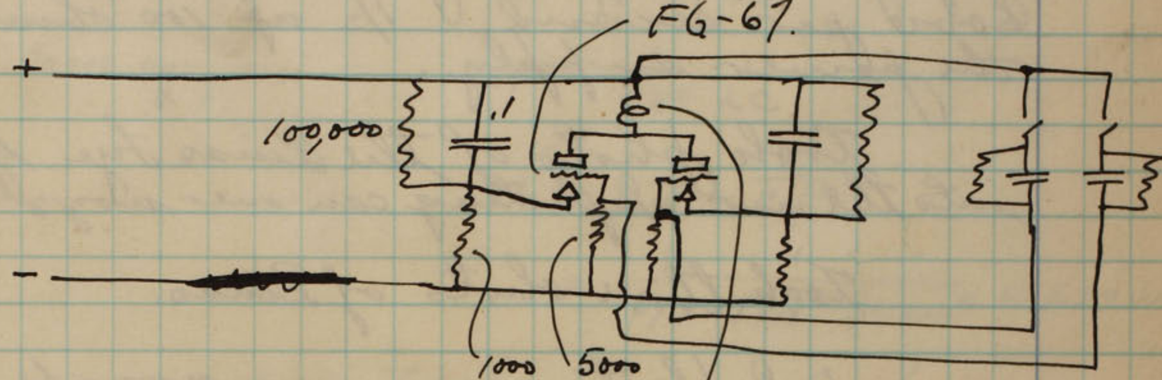
Data on focus Short mount 16" → inf
+3/16" 9.5 → 13.5

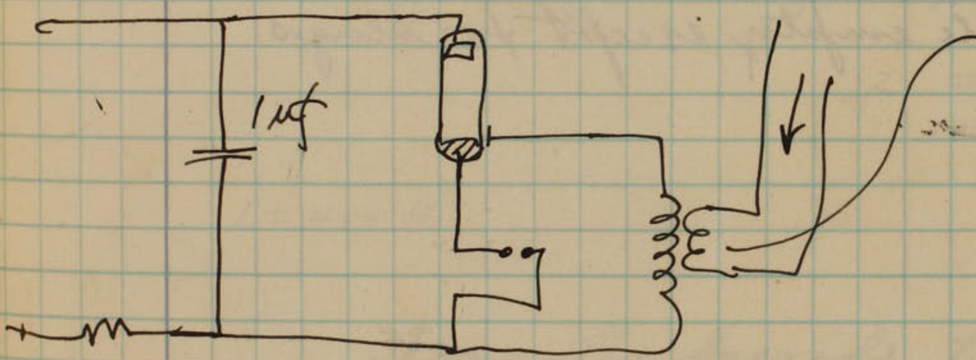
long mount 4 7/8 - 6"

Oct 28/1933
H.E.E.

Shadow Spark outfit.

Finished wiring up push push thyratron pulse amplifier yesterday.





Oct 29 1933
H.E. Edgerton.

Spent yesterday with Robertson of Lever Brothers working on movie of the soap spray. Used Hg controlled spark gap for taking the photographs at 6000 per second. 1/2 uf 100 ohms to the power supply.

Took photo of the Rinso Lye spraying into the air. Deflecting can over nozzle.

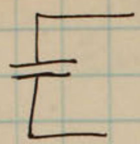
Took three shots of Rinso.

1. Deflecting can over nozzle. Results not very good.

2. Thin stream with turbalance.

3. Nozzle empty except for slugs.

Small Strobo with direct discharge ~~Oct.~~ Nov. 2, 1933.
H.E. Edgerton



$C = 8\ \mu f.$

$f = 50{,}000$ cyc/sec.

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

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

$$L = \frac{1}{4\pi^2}\frac{1}{Cf^2}$$

$$= \frac{1}{39.4}\frac{1}{8\times10^{-6}\ 25\times10^{8}} = 1.27\times10^{-6}\,h.$$

Try $f = 10{,}000$ cycles/sec.

$$L = \frac{1}{39.4}\frac{1}{8\times10^{-6}\ 10^{8}} = 3.2\times10^{-5}\,h.$$

$f = 5{,}000$ cycles/sec.

$$L = \quad .0001.27\times10^{-4} = .0001\,h.$$

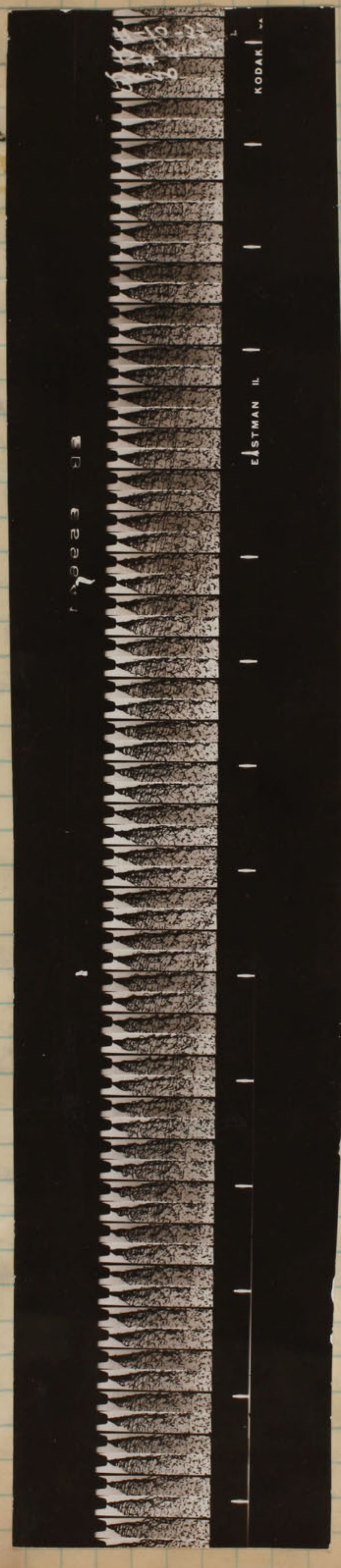
$L = 4\pi r N^2$

I ran the Hygrade tube no 1 for four days (8 hours each) with one ohm resistance in series with a 7.5 uf condenser charged to 345 volts ~~from a~~ through a 400 ohm resistor. frequency about 20 per second.

The tube darkened slightly but still works ok. The ~~[illegible]~~ commutator was badly worn by the large ~~peak~~ currents. (tube no ^

Started a life test with 4 millihenries inductance, 8 ohms R. in series. The tube seems to give as much light and the sparking at the commutator is greatly reduced. Changed from tube 1 to tube 2 after two hours test.

See page 36.



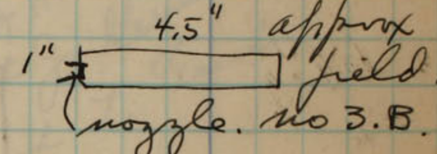
Sept 13 1934
Pasted in.
75 #
11-10-33. shot.
Soap
6000/sec

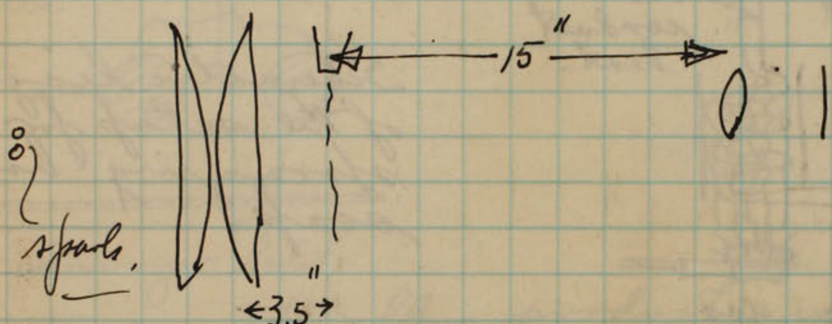
Nov. 5. 1933
H E Edgerton

Rinso Pictures 6000 shadow.

Picture No 1. Rinso came out with spraying. stream of soap no action. not saved! N.G.

Picture No 2. Seemed ok. 150 pounds. Excellent Picture!!





Pict. 3. Rinso Lye Low pressure 135 degrees. Shield to cut off spray.

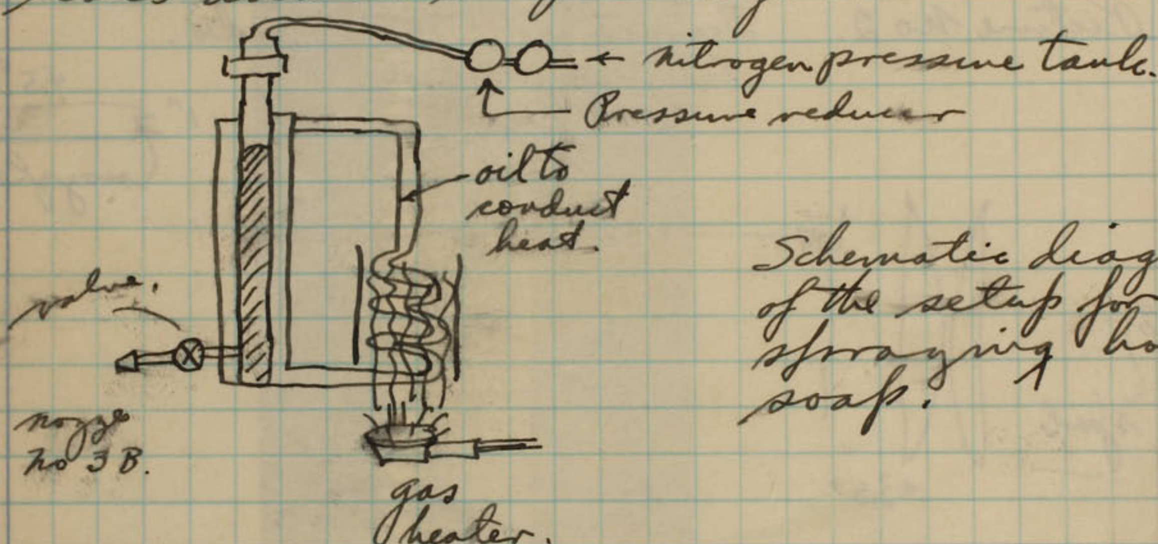
Pict 4. Rinso Lye Low pressure at angle to get edge of the normal spray. Some misses in pict.

Picture 5 " " Same but dif angle of noz. no miss Beautiful shot!

Nov. 11, 1933.
H. E. Edgerton
K. J. Germeshausen
Robertson.

6000 per second motion picture of Rinso Crutcher soap.

A valve was put between the nozzle and the soap heater for these tests and it helped a great deal.



Schematic diagram of the setup for spraying hot soap.

Two pieces of film were taken at 6000 p.s. One at 75 pounds pressure and the other at 50?.

During the last week I assembled the motion picture film of new high speed pictures. Some of the subjects

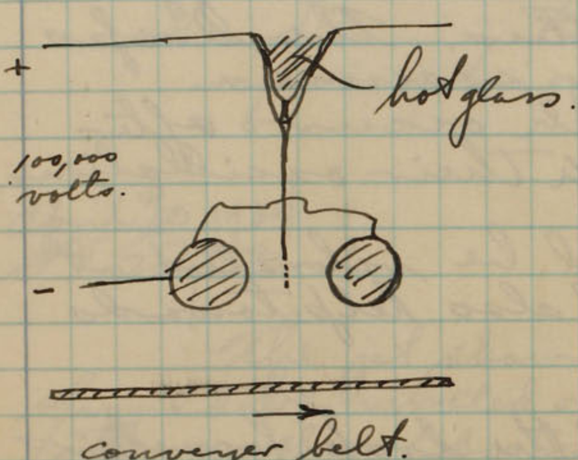
Canary in flight.
Water jets.
Splashing of liquids
Spider ~~[illegible]~~ scared.
Snapping of the fingers
Winking of the eye.
Snake's tongue
Cavitation. etc.

Nov. 14 1933.
H. E. Edgerton.

On last Friday I spent an hour with Mr. Fogler and Mr. Slater of the glass co talking about methods of making glass wool.

I am to look up schemes for kenotrons and for induction motors to stretch the glass out into thin threads.

Witnessed Dec. 12, 1933
Explained by H. E. Edgerton
Kenneth J. Germeshausen
Frank L. Tucker



or air jet to blow product away.

The electrostatic pull may be too great in the neighborhood of the jet because of its pointed nature. This can be remedied by the use of metal edges to distort the field.

A large tank could be put at the bottom to catch the product.

Heat can be applied at the top.

Nov. 14, 1933
H. E. Edgerton.

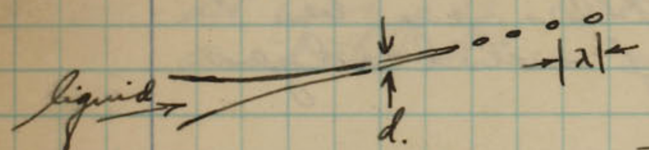
A method of making steel shot or other kinds of metal shot having nearly the same size.

If a nozzle squirts a jet of liquid it is known that the drops form as a function of the hole in the nozzle. Our movies show this. The drops need to cool after they assume a round shape which occurs after they go ~~into~~ through their oscillations.

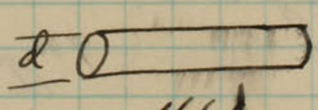
The nozzle could be vibrated at a rate which would also help towards uniformity of the drops.

The wave length of the drop formation is about 4.6 x the diameter of the jet. If I remember correctly an article I recently read in the Phil. Mag. of this year. (Aug?)

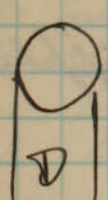
$$\lambda = 4.6 \times d.$$



size of the drops



$$\text{volume} = \frac{\pi d^2}{4}\, 4.6d \qquad \frac{D^3}{6.9}$$



$$\text{sphere} = \left(\frac{4.6\pi d^2}{4}\right)d = \frac{1}{6}\pi D^3$$

$$d^3 = \frac{4D^3}{6 \cdot 4.6} = \frac{4D^3}{27.6} \qquad d = \frac{D}{1.9} \text{ approx.}$$

This is the relationship between the diameter of the jet and the diameter of the droplet.

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

Let D = ~~.003~~ ~~.01~~ .1 of an inch.

~~$d^3 = \frac{4 \times .1}{27.6} = \frac{.004^3}{27.6}$~~ =

jet diameter = ,05"

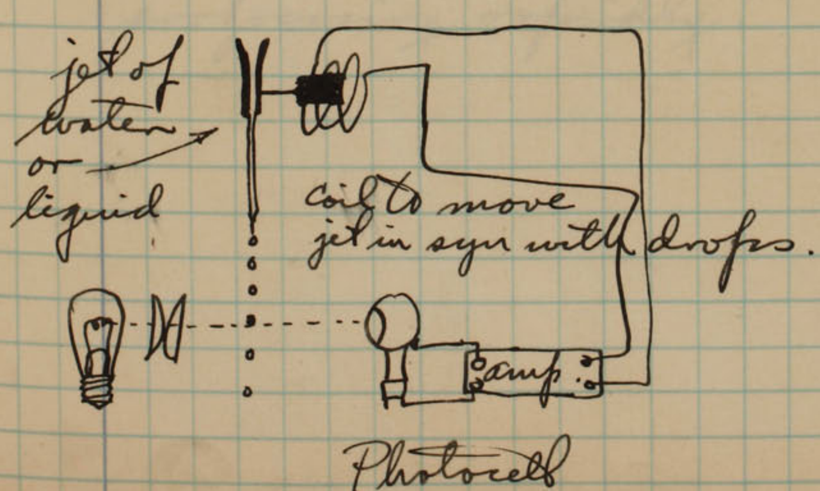
Showed movie to Vandeerpyle and Holden regarding this on saturday.

April 30. 1934.
H. E. Edgerton.

The jet shown on the preceding page should be vibrated at a speed ~~ft~~ to correspond to the number of drops formed per second. this is the speed in ft/sec of the liquid going through the nozzle

freq of osc = (4.6 × d) × speed of liquid.

The light from a photo cell could be interrupted which would always synchronize the size of the drops with the vibrations.



Nov. 25. 1933.

More movies of Rinso 6000/sec.

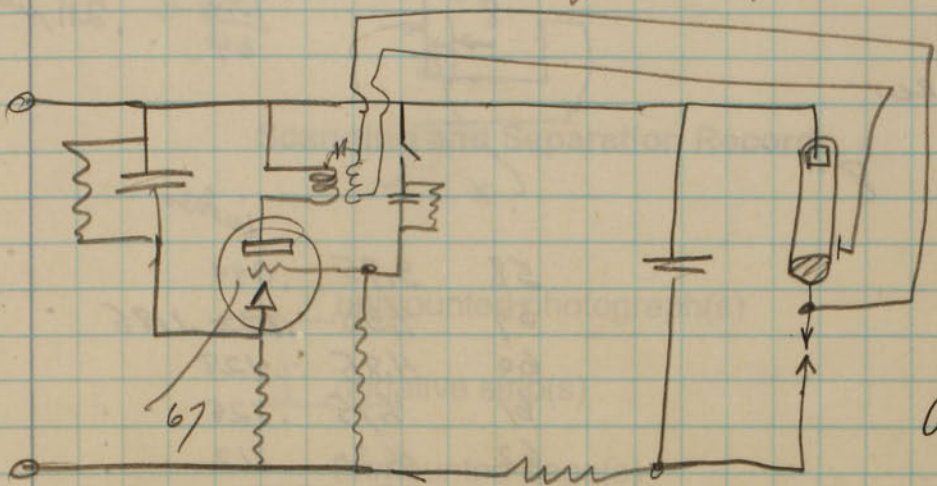
Pictures on Nov 24 Rinso Crutcher
~~180°~~

Pictures on Nov 25. Neat Kettle Soap.

ok but soap on lens.	160°	100 #
film broke.	190	100 #
obstruction in lens.	185	100 #

Nov 26 1933.

Exp. with spark driven by a
Hg tube for source for reflected pictures.



Blew up spark coil

Nov. 28, 1933.

Mr. Horton of the Trico company came to Boston this morning and spent all day. We took 3000 a sec. movies of ~~the~~ his vacuum operated horn. Also took stroboscopic movies of the motion of the diaphram through a glass window on the side.

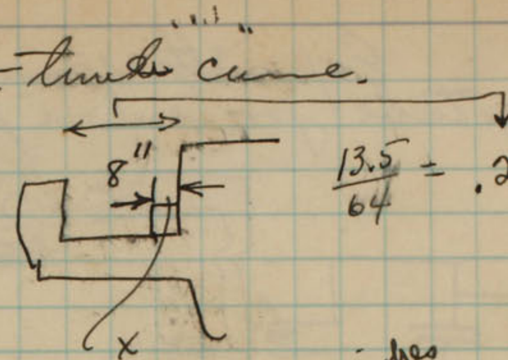
I talked to Ben Fogler this noon about the glass drawing scheme shown on page 43.

Spent some time with Wilkins at the G.R. this afternoon. The design of the camera is progressing rapidly.

Nov. 29, 1933.

H. E. Edgerton.
E. C. Horton.

Deflection - time curve.



$\frac{13.5}{64}$ = .211 inches

time in 1/3000 sec.

0	1 3/4	8"
4	1 7/8	
5	1 15/16	
6	1 7/8	
12	2 1/8	
13	2 3/16	
14	2 1/4	
15	2 7/16	
17	2 3/4	
19	2 15/16	
20	2 15/16	
24	3 or 2 15/16	stopped.
19	3 1/16	

0	1.7"	~~.10"~~ .045
6	1.65	.0435
10	1.75	.046
15	1.90	.05
20	2.25	.059
25	2.9	.076
30	3.0	.079
35	3.05	.080
40	3.25	.086
~~45~~	~~2.9~~	
42	3.25	.086
44	3.05	.08
46	2.95	.078
48	3.30	.087
49	3.6	.095
50	3.7	.0975
51	3.7	.0975
52	3.4	.090
53	2.9	.076
54	2.4	.063
55	2.1	.055
56	2.4	.063
57	3.0	.079

		inches
58	3.75	.099
59	4.50	~~.132~~ .1185
60	4.85	.128
61	4.75	.125
62	4.30	.112
63	3.45	.091
64	2.35	.062
65	1.5	.0395
66	1.6	.042
67	2.35	.062
68	3.55	.094
69	4.8	.127
70	5.65	.149
71	6.0	.158
72	5.7	.150
73	4.95	.1305
74	3.7	.098
75	2.15	.057
76	1.1	.029
77	1.14	.03
78	2.55	.067
79	4.20	.111
80	5.65	.149
81	6.55	.173
82	6.75	.178
83	6.45	.170
84	5.3	.140
85	3.7	.098
86	2.0	.053
87	.9	.024
88	1.35	.036
89	2.8	.074
90	4.5	.119
91	6.0	.158

Notebook Number: T-4

Scanning and Separation Record

____unmounted photograph(s)

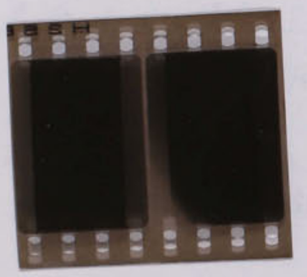
_1_negative strip(s)

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

was/were scanned where originally located between page 48 and 49.

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

.38



.38

Def in inch = $\frac{.211}{8}$ x

= .0264 x.

		inches
92	7.0	.185
93	7.15	.189
94	6.65	.175
95	5.50	.145
96	3.9	.103
97	1.95	.051
98	.65	.0171
99	1.3*	.034
100	2.85	.075
101	4.6	.121
102	6.1	.161
103	7.0	.185
104	7.25	.191
105	6.6	.174
106	5.5	.145
107	3.9	.103
108	2.0	.053.
109	.65	.0171
110		

— } 7.4 max. .195
.65 min. .0171
7.05 max .186
.85 } min .022
.90 .024
7.0 max. .185
.65 min .0171

6

2000/60.

2000/90 100 .001

Dec. 1, 1933.
H. E. Edgerton.

Assembled Trico film and Germeshausen sent it off to New York, George Bean at 40 Wall Street). About 300 ft long. It contains strobo movies as well as high speed movies at 3000 a second.

Spent afternoon at the ~~Lever~~ Lever Bros company in Cambridge. Mr. John Bodman called in a group to explain the coming session with the lawyers to them. Each man is to give a talk on his special specialty.

Germs took the high speed camera over to Lever Bros ~~on~~ this ~~m~~ morning and took a few shots. Apparently the lamp worked at first.

Reluctance motors (synchronous) ~~often~~ come up to speed with either pole as north. This usually is alright since in most applications ~~there is no difficulty in~~ it makes no difference as the motor runs at synchronous speed.

There are uses, however, where it is very important that the motor always comes up to synchronism with the same pole in the same corresponding field. A motor of this type would be needed for the small motor 40 in my application No 675,348 Dated June 14, 1933.

I propose to make a small synchronous reluctance motor with a winding on the rotor which is connected to a copper oxide rectifier. The rectifier can be put on the rotating member so that no slip rings are needed.

~~S~~ Syn. motor Demonstration outfit for use at Worchester ~~next~~ ~~[illegible]~~ two weeks from now.

Dec. 2, 1933.

Spent morning at Lever Brothers plant spraying Rinso in an actual nozzle. Two pictures were taken, one with steam and ~~one w~~ one with air.

Dec. 6, 1933.
H. E. Edgerton.

Just finished a demonstration at the St Andrew's Chapter of the Boylston st. masonic temple. Herb. Grier helped me set it up and with the demonstration. We showed the movies.

Mr. Hall of the Victor Ring traveller company ~~was here~~ will be in Cambridge on Friday afternoon and Germeshausen is going to take some pictures of the ring travellers.

Pease was over this afternoon and ~~showed~~ talked about the program for next week.

Dec 11, 1933.
Spent all day (Dec 7) in New York with George Bean at his office 40 Wall St. Mr. E. C. Horton of the Trico company was there, also Mr. Bean from Buffalo. Went over strobo movies and observed the vibrations of an E. A. Horn. Discussed fully the stroboscope and the camera with Bean.

Lunch with Welch Pogue (41 Broad st) and Frank Tucker (A. D. Little.) and the others mentioned above.

Dinner with Welch and Mary Ellen at their new home at 21 West 11th. Richard and William there. Saw 3 pigs & Henry VIII in evening. Returned to Boston on the "Owl".

On Friday noon Bush told me about Ralph Bennett's wife and I went out. She died about 2:30. He stayed with me that night and the next day, then going to the Durshams.

Dec 11. 1933,
~~H. E. Edgerton.~~

Pease was over and we talked about the film. Kleinsmidt of A. D. Little Co. told us about his talk on spray jets for next thursday. then we took him over to our lab. and saw off the reels on the stearine and the soap.

I talked to Fogler at noon about the scheme for stretching ~~ooo~~ glass by means of electrostatic forces. (This is on page 43 and 47) He gave me a copy of his sketch which he witnessed on Nov. 28.

The maximum pull on the filament will depend upon the maximum gradient which can be established in the air or gas surrounding the glass filament. One methods of increasing this breakdown (electrical gradient) is to increase the pressure. Thus the material could be stretched in a chamber at a high pressure. Low pressure also would work but difficulty may be experienced in getting a sufficiently low vacuum.

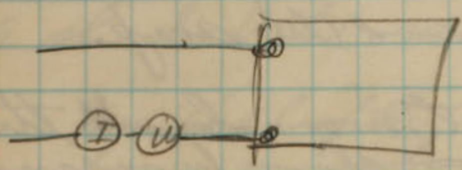
H. E. Edgerton 12/12/33

Explained by H. E. Edgerton
Frank L. Tucker
Kenneth J. Germeshausen

Dec 21 1933
H. E. Edgerton.

Test of strobo which was used this summer at Bellows Falls.

West.
\$25.00 230. 35.
23.00
Mr. Sprg. E4796
10-1110

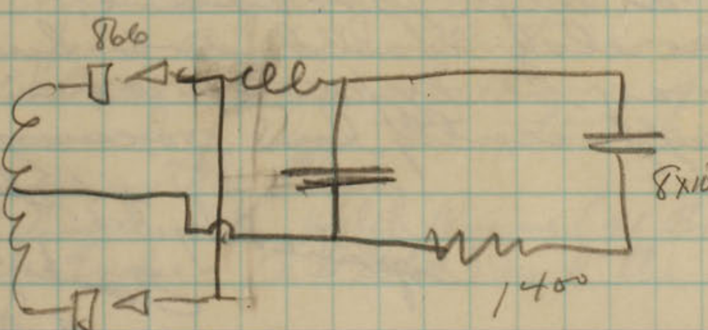


30 flashes sec. 2.65 a 240 watts.
filaments etc 1.4 85 "
155 watts

77 watts in condenser.

$\frac{CE^2}{2} = \frac{77}{30} = 2.5$ joules.

$E^2 = \frac{2.5 \times 2}{8} \times 10^6 = .625 \times 10^6$ E = .850. volts.



12 ~~mf.~~ × ~~500~~ 400 8 × 10^{-6} = .006000 sec. .03 sec.

8 × 400 × 10^{-6} = .0032 sec. $\frac{1}{.03}$ = 33 flashes/sec.

.01

at 60 cycles. $\frac{CE^2}{2} = \frac{8 \times 1000 \times 1000 \times 10^{-6}}{2} = 4$ joules.

4 × 60 = 240
+ 240 in circuit = 500 watts.

Charging resistance reduced to 500 ohms.

3 ft tube Hg each end. cold 400 watts at 60 cycles.

Drops to 380 w 4.07 amps when hot.

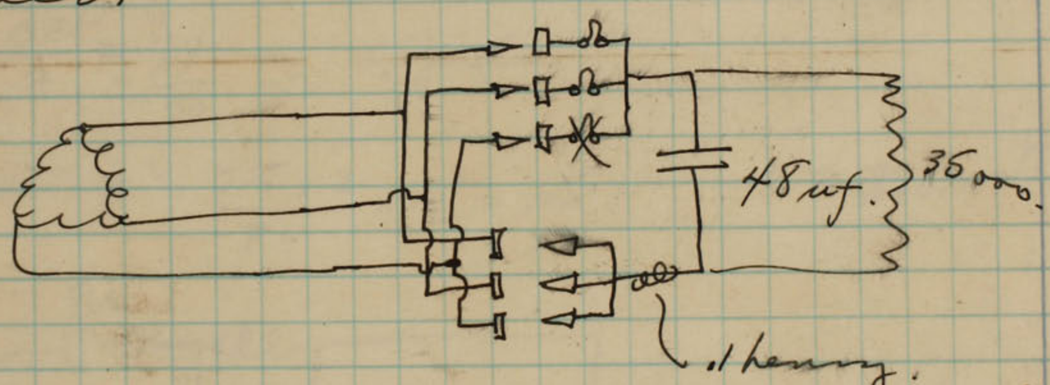
Jan 6 1934
H E Edgerton.

Spent wednesday Jan 4 with the Lever Brothers co. showed them the movies and pictures of the soap work. the lawyers were all there.

Experiments with power Supply.

Put on a Westinghouse circuit breaker today. Removed time switch and relay. Also put in 6 new FG 32 Rectifier tubes to replace the old ones.

Connected oscillograph to read the peak currents in two of the anodes.



Osc. 1. Calibration 9.98 amps on each.

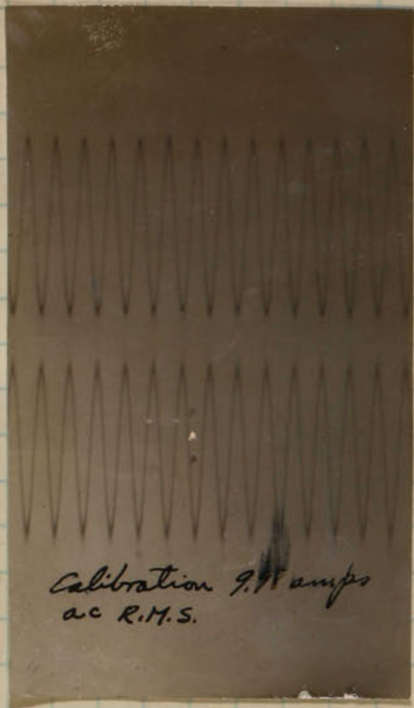
Osc 2. 0.1 ± henry choke in common lead
350 ohms across it.

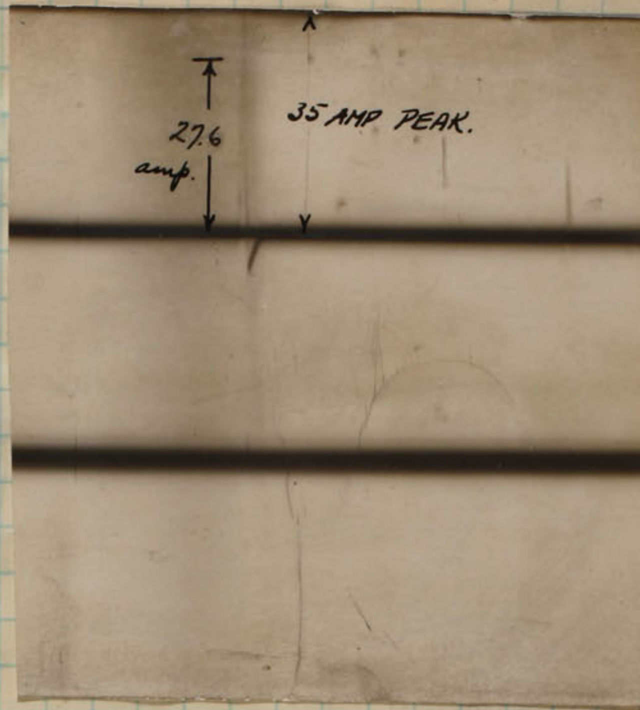
Osc 3. 2h ± choke in common lead.
Several starting transients superimposed.

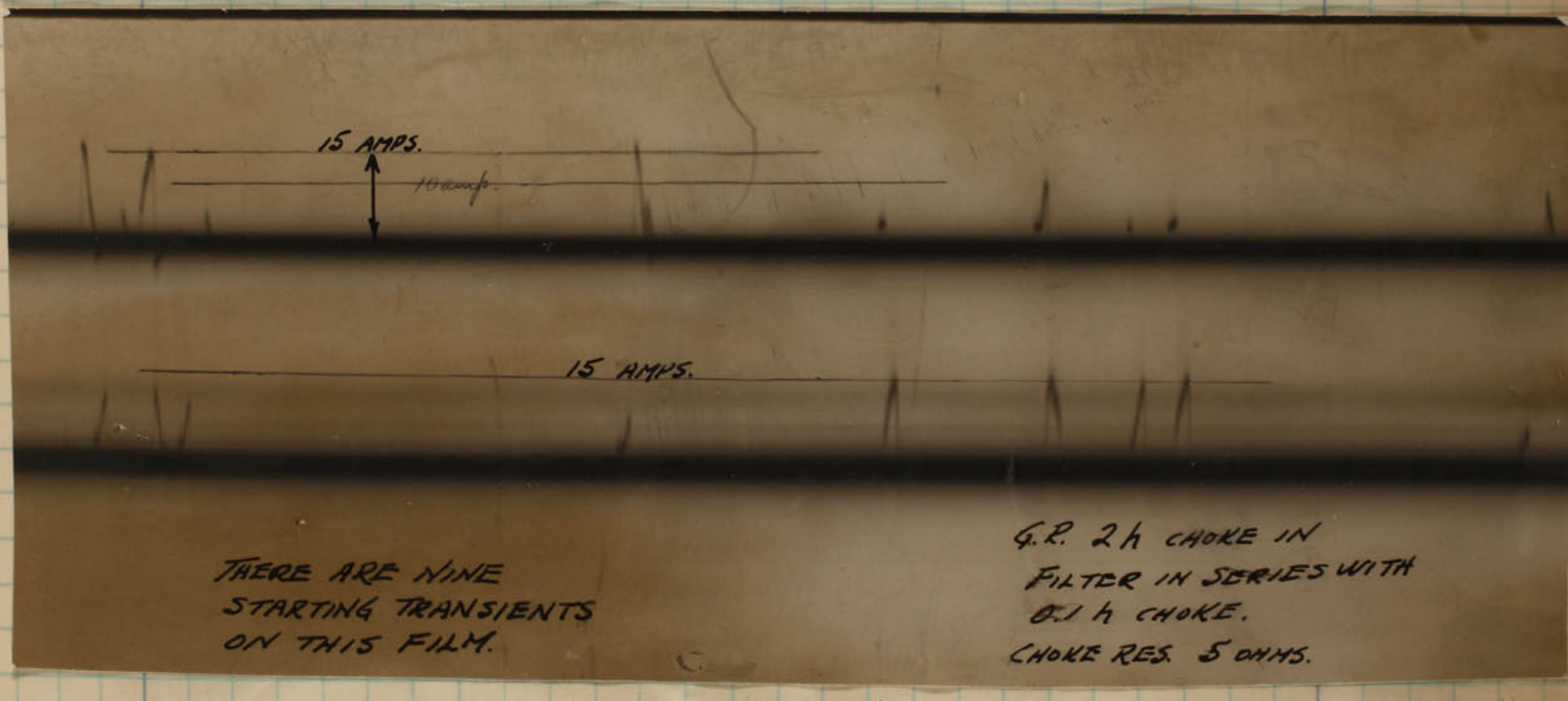
Those present.
Bokman
Pease
Maxwell
Stevenson
Fogler
Fourtney.
Germeshausen.

Davis McAulley
Hogue
Davis

Coyrdray.
White
Bernard.


Calibration 9.8 amps
ac R.M.S.

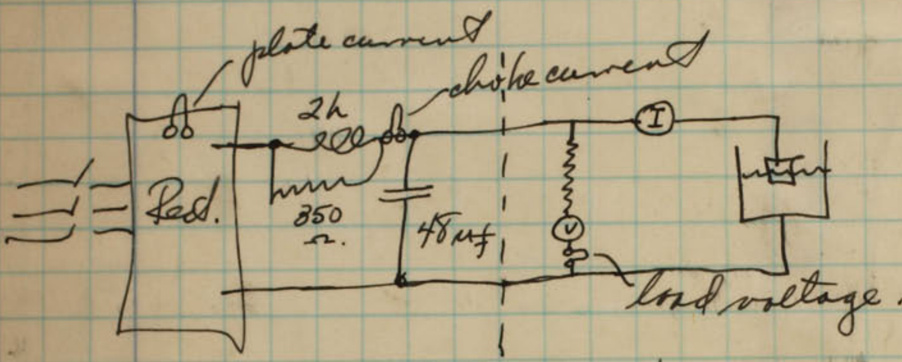

27.6
amp.
35 AMP PEAK.


15 AMPS.
10 amp.
15 AMPS.
THERE ARE NINE
STARTING TRANSIENTS
ON THIS FILM.
G.R. 2 h CHOKE IN
FILTER IN SERIES WITH
0.1 h CHOKE.
CHOKE RES. 5 OHMS.

Jan 7 1934

Further tests of 10 KW Power Pack.

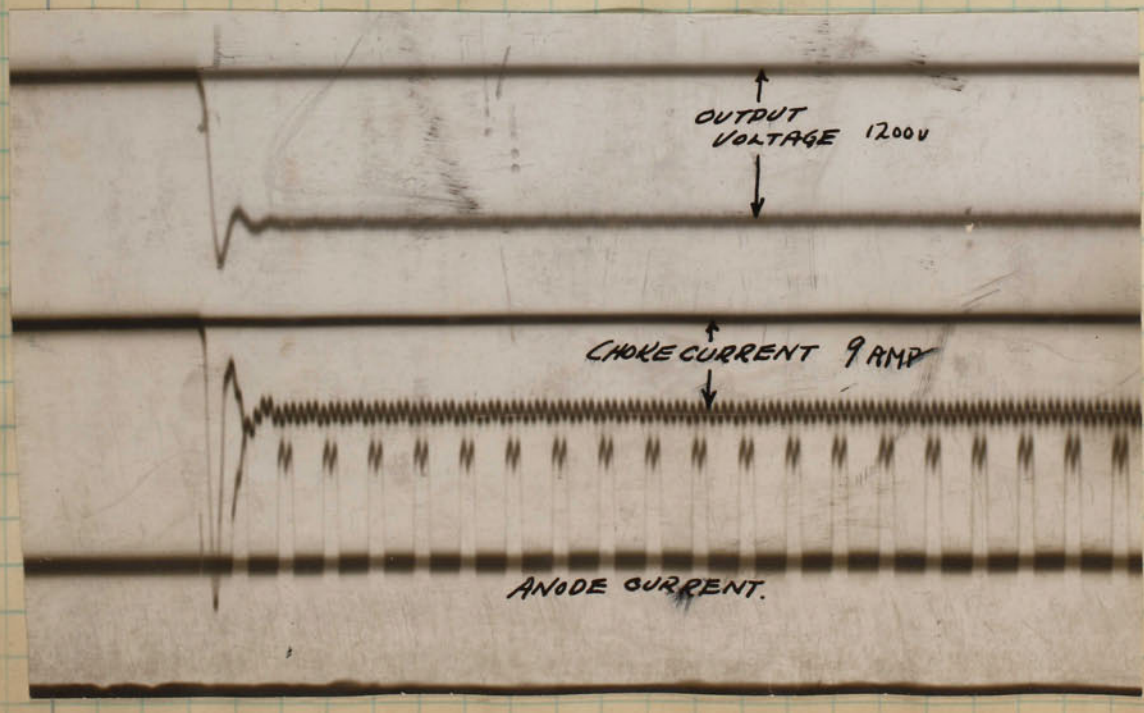
Water box load arranged for carrying load of 5 to 10 amps at 1000 volts.



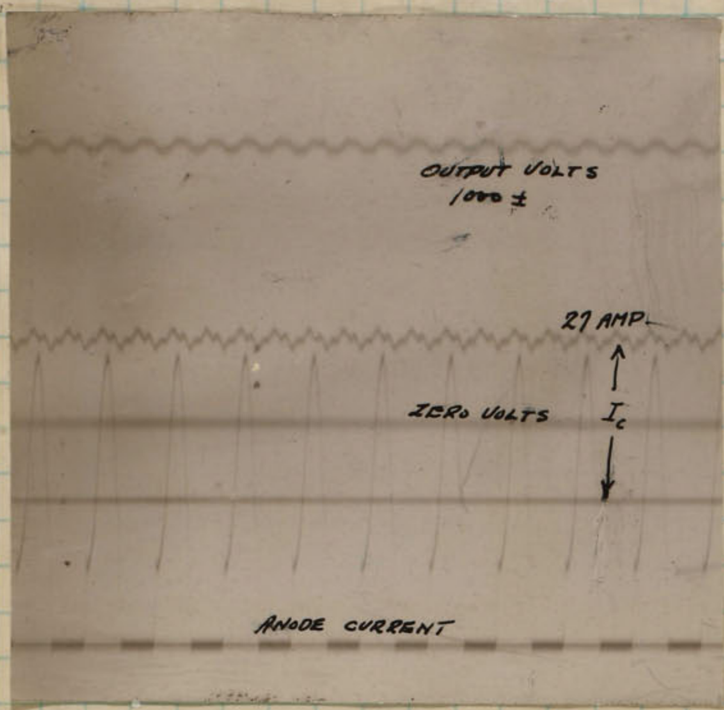
Conditions for oscillograms shown below.

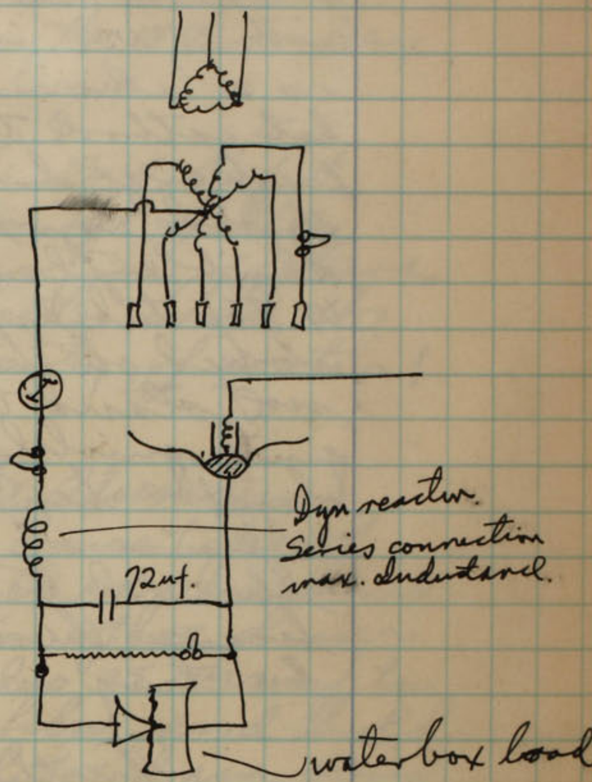
Output voltage 1200.
" current 9 amp. this changes as the water box warms up. It usually increases slowly. this current may be only 8 amp when the switch first closes.

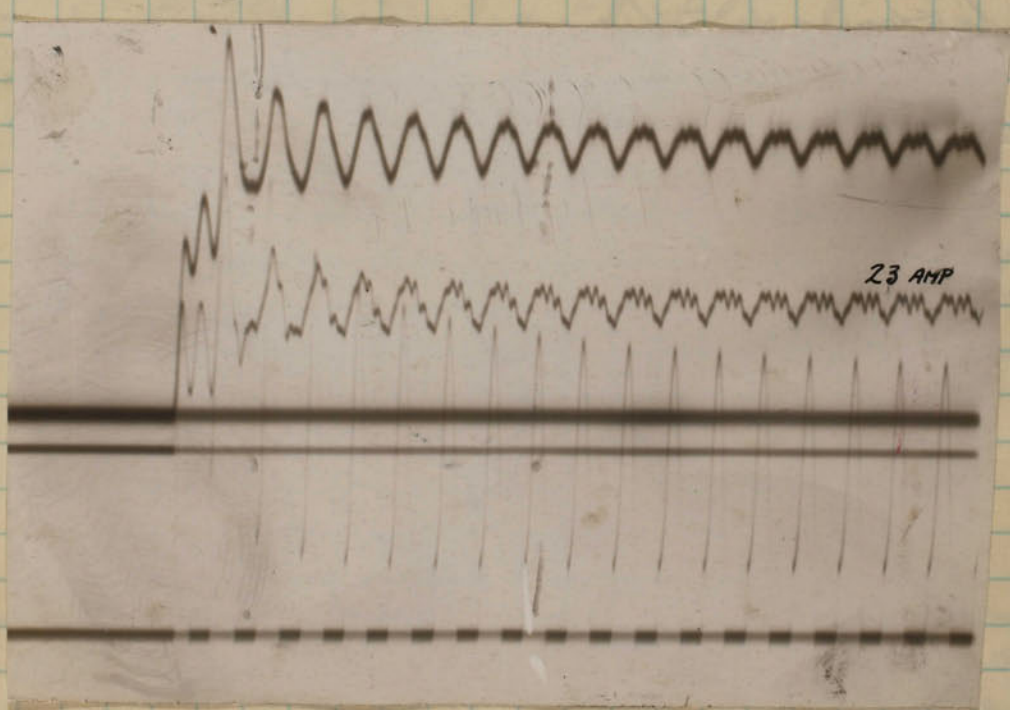
Anode current 3 amps - approx.



Oscillograms taken Jan 10, 1934. 6 phase Raytheon hot cathode rectifier.
Primary Δ Sec. Star.





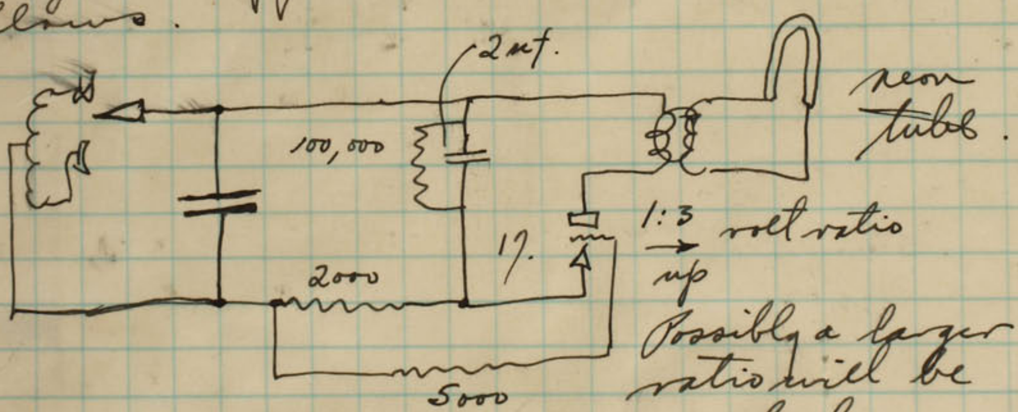


McDonald of the Raytheon was here for these experiments. We also took high speed motion pictures of the arc in the tube by means of the Erpi h-s camera borrowed from Lever Co.

Jan 15 1934
H E Edgerton

We have been working for some months past with the G.R. Co on a small stroboscope for use as a tachometer. The idea was to use a hot cathode tube and switch a condenser discharge directly into the tube. The Sygrade company built a tube with a double filament (similar to that of the UX 866 tube except two of them). The filament worked ok but the contactor could not stand the strain and went bad quite quickly in service. A choke of about ? henries increased the life at the expense of a long flash time. This should be satisfactory however because there is a certain amount of hunting in the governor controlled.

Another circuit that should be satisfactory for this service is as follows.



Germeshausen left yesterday noon for Columbus Ohio to talk to the Illinois Owens Glass co. about electrostatic pulling of glass.

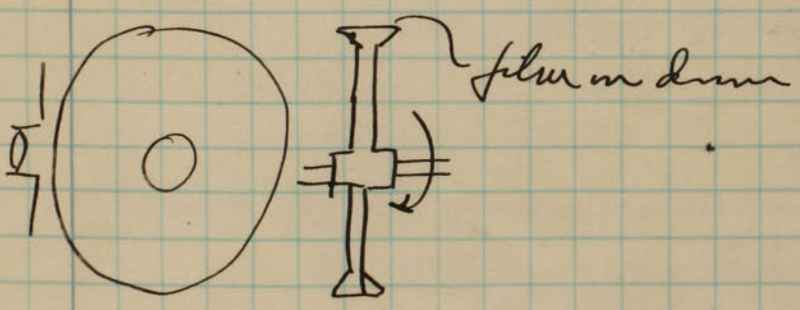
Spent several hours in the evening with Wilkins (G R Co) talking about the camera.

Last week I spent all day thursday Jan 11 1934 with E.C. Horton who brought with him Dr. Thatcher's affidavit from N.Y. Also spent all day the 13th working on my reply.

Venard and   of the M.E. Dept took out a piece of glass from the Pelton wheel and I took some motion pictures of the water hitting the buckets with the stroboscope. There was plenty of water!

A pattern was sent to the Aluminum company on Jan 12 (?) for a drum type of camera which I am going to experiment with. This camera consists of a drum 1 ft in diameter and holds 35 mm film.

I plan to splice the film and hold it on by friction. If it slips I am going to put the wheel and film in a chamber and pump it down so that the evaporation of the ~~film~~ water in the film will shrink it on the drum.



High-speed film.

Jan 16 1934.
H.M. Edgerton

Progress of High-Speed Moving Pictures for Lever Brothers Company

July, 1933. First pictures of stearine dropping from a nozzle, and of stearine spray at 500 pictures per second.
Milk-drop motion pictures (1500 pictures per second).
Attempt to analyze the motions of milk drops from pictures accurately timed (1020 pictures per second). Pressure 3, 6, and 12 lbs. No results of any value from this experiment.
New high-speed camera completed.
Experimented with high-speed circuits for several weeks.

July 30, 1933. Took pictures at 3000 per second.
Devised method of enlarging and reprinting small pictures which was very useful in this study of particle formation.

Aug. 9, 1933. 6000 pictures per second.
Further work to increase camera acceleration.
Experimented with stearine spray and took high-speed closeup movies.

Sept. 22, 1933. Showed preliminary reel on stearine-particle formation and dilute-soap experiments to Messrs. Bodman, Maxwell, Squires, Pease, Robinson, and Stevenson. More scenes were suggested at this preliminary review.

Oct. 28, 1933. Further development of spark shadow apparatus which greatly improved the quality of the high-speed motion pictures.
Pictures of Rinso liquid phase in pressure spray gun.
High-speed movies of Rinso from special heated pressure tank.

Nov. 5, 1933. Further work on Rinso and Rinso liquid phase.

Nov. 11, 1933. Rinso pictures.

Nov. 25, 1933. Neat kettle soap.

Dec. 1, 1933. Moved camera to Lever Brothers factory to photograph Rinso in a production nozzle.
Repeated stearine pictures and re-edited the reel.
Attempt to photograph Lamont conditions.

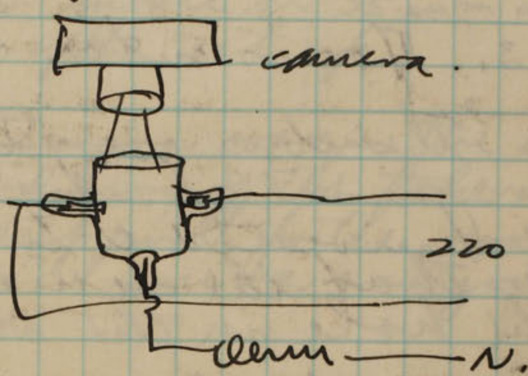
Jan. 4, 1934. Showed two reels of motion pictures to Lever Brothers representatives and to their attorneys.

Jan. 17, 1934
H. E. Edgerton.

Had lunch with Bugh and discussed the stroboscope and the high speed pictures.

Grier and I set up the E.R.P.I. Camera and took some motion pictures of the cathode spot on a mercury-arc tube. A special window on the top of this tube gave us a clear view of the cathode surface.

We took pictures on both negative and positive film.



Germeshausen went to Columbus, Ohio to discuss the electrostatic problem with Slayter of the Illinois Owens Glass Co. Returned on the 17th.

Jan 20 1934
H E Edgerton

Movies of Old Gillette Razor showing breaking of the blades. For Prof. Norton

No 1. Camera jammed. 40 ft 1200/sec.

No 2. Razor did not break blade while exposure was ok 40 ft

No. 3. Focus out on corner. 40 ft.

The above were taken with 4 1" tubes in parallel at 1200 per second. An inverted U tube was connected so that the camera shot through the hole in the middle.

No 4. The breaking is so fast that it is all over in less than 1/1200 th of a second.

Jan. 25, 1934.
H. E. Edgerton.

Lined up camera and took 6000 per second movies of the breaking of the corner of a razor blade on a damaged Gillette razor.

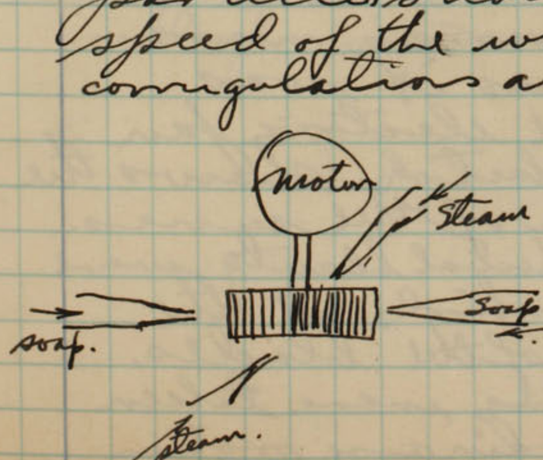
This picture was fairly good but the blade still broke between exposures showing that the break is ~~about~~ less than 1/6000th of a second in duration.

Jan 27, 1934. Copied razor movie on 35 mm and took several scenes of the set up.

The high speed camera was in the shop this morning for remodeling of the take up motor drive. A support for the motor was built and a new universal joint was constructed.

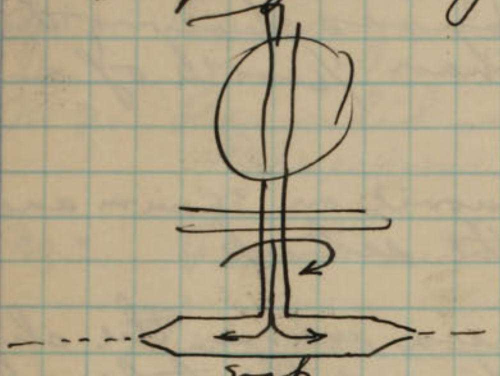
Atomization methods of treating soap and other ~~processes~~ materials.

1. Squirt a stream of soap against a rapidly rotating wheel with a rough or corrugulated surface. Probably two streams from opposite sides will be used although more can be. Jets of steam can be used between the soap nozzles for cleaning off any soap that sticks. The size of the particles should be a function of the speed of the wheel, the number of corrugulations and the velocity of the jet.



The out fit could be put in the top of the drying tower hung from the top as shown in the picture.

Another method of atomizing the soap would be to rotate the nozzles at a rapid rate. Centrifugal force would accelerate the soap and the windage would break the soap up into particles. A connection for putting the soap in would be rather difficult but could be made I am sure. I have shown a motor with a hollow shaft.

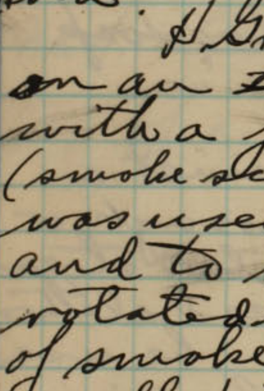


Explained Jan 30, 1934
Kenneth J. Germeshausen
Herbert E. Grier

Jan 28, 1934
H. E. Edgerton

H. Grier and I worked yesterday afternoon on an ~~exp~~ interesting experiment with a fan and tetanium tetrachloride (smoke screen chemical). A stroboscope was used to illuminate the fan and to stop its motion so that it rotated very slowly. A filament of smoke was produced by using a small piece of cloth on the end of a wire and saturated with the smoke material.

Very interesting curves were made by the smoke as it was periodically cut by the electric fan blades. The below sketch shows the form of the curves.



Of especial beauty were the whirls at the tips of the blades.

Motion pictures were taken with an ordinary motion picture camera since the flashes were fast enough to give several flashes per frame.

Jan. 29, 1933 4

Harold E. Edgerton.

Data on coils from the G. R. Company.

#1 450 turns of 20. pri ind 0.5 mh +
1350 " of 36.

#2 450 turns of 20
1800 turns of 36.

Jan 30 1933 4

Fred Dellenbaugh came in and we discussed the tests on the 6 phase rectifier made ~~to~~ several weeks ago when McDonald was over.

G. L. Day called from N. Y. about the spark photography apparatus for some photographs of gas engines. He is going to call back later after I have checked up with Gen. Radio.

Wilkins (G.R) was over and I gave him a diagram of the spark apparatus so that we can quote Day a price. Wilkins got the two 35 mm 20 picture sprockets which Harry Lawrence and Joe Godimer made.

Took movies of the stroboscope, fan and large electric motor to be put in the reel for interesting shots.

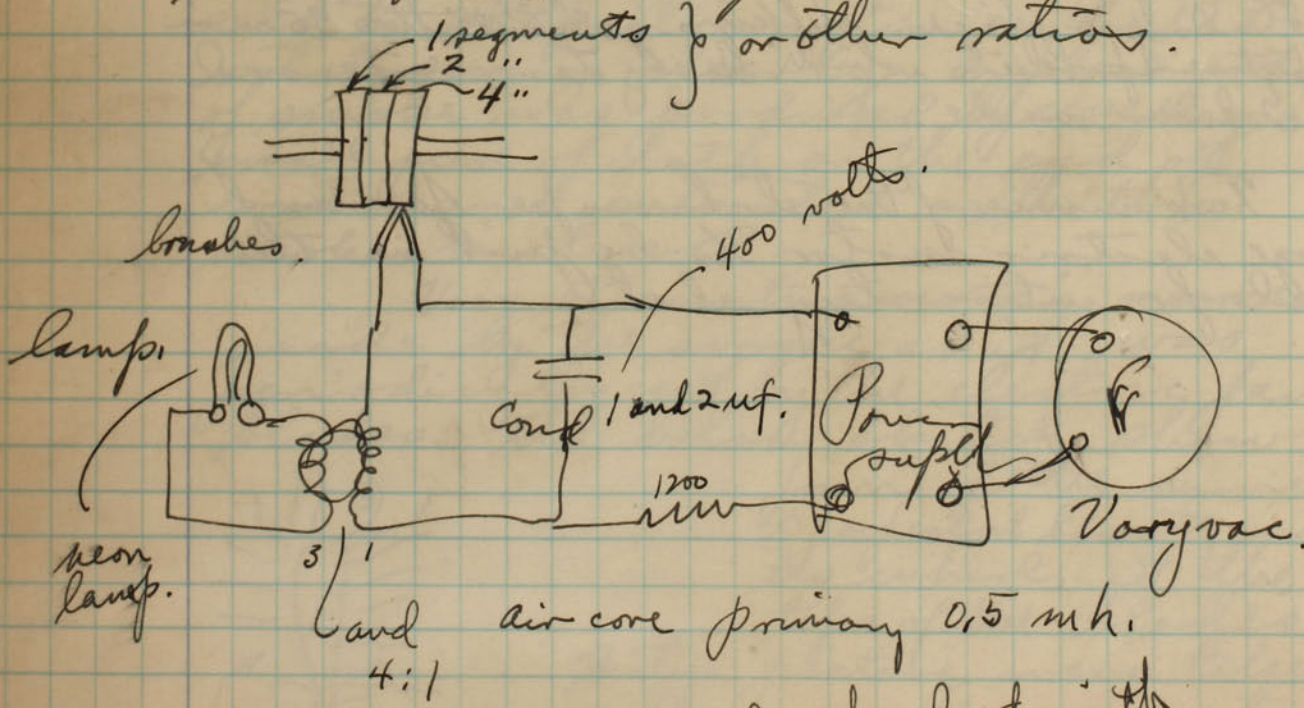
Jan 30 1934
H.E. Edgerton.

Spark apparatus for photographs.

Voltage?. How many units?
Capacity?. Reflector?
Gap

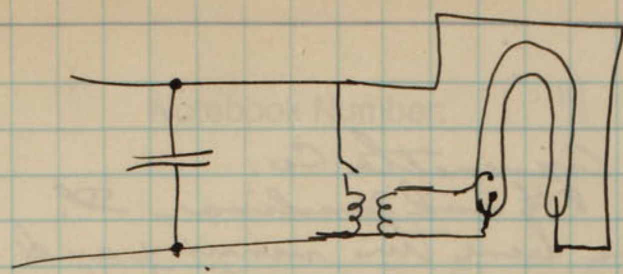
Jan 31 1934
H.E. Edgerton
& K.J. Germeshausen
Talked at Malden Rotary (Hinckley telephone).
Masonic dinner for Cliff Scully.
~~Small Stroboscope experiment.~~

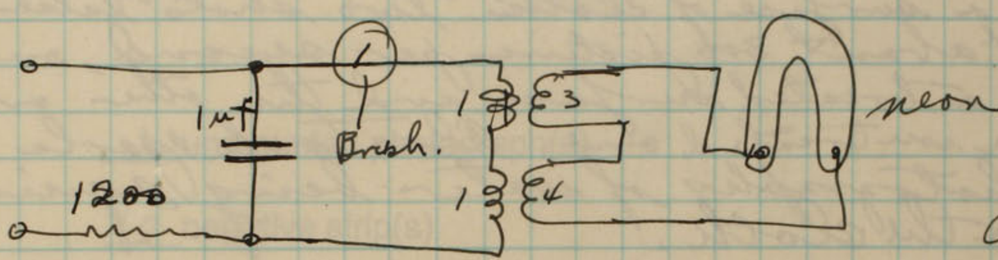
Scale multiplication of a mechanical tachometer by means of multiple commutator segments or multiple sets of brushes.



Works o.k. but with some sparking at the brushes

tried it with both transformers in seri





Coils described on p. 67.

works ok and with less sparkings at the brushes.

Make transformer with primary impedance of 2 mh 4 to 1 ratio.

10 mh 4 to 1 ratio.

Feb 3 1934
H E Edgerton

F. S. Sundemann   Cravenette Co.
Trangmar   8th and Madison St.
Dr Taylor were here this morning and we took some movies of drops of water splashing on a surface of cloth. Two shots taken at about 300 pictures per second, one on a treated surface and the other on an untreated one. Also took spark photographs of water being squirted on the cloth.

Feb 4 1934

Reprinted the high-speed picture of the Gillette razor breaking the corner of the blade, last night. It came out fine.

Took a series of high-speed movies at 1200 per second of milk drops splashing on a surface of milk. They look great! are to be put in the reel of movies.

We have been working with Welking of the GR on a small stroboscope. Germeshausen wishes to use the charging current to record the frequency and it looks like it will work if the apparatus is continually checked ~~and~~ upon a small motor of known speed.

Notebook Number: T-4

Scanning and Separation Record

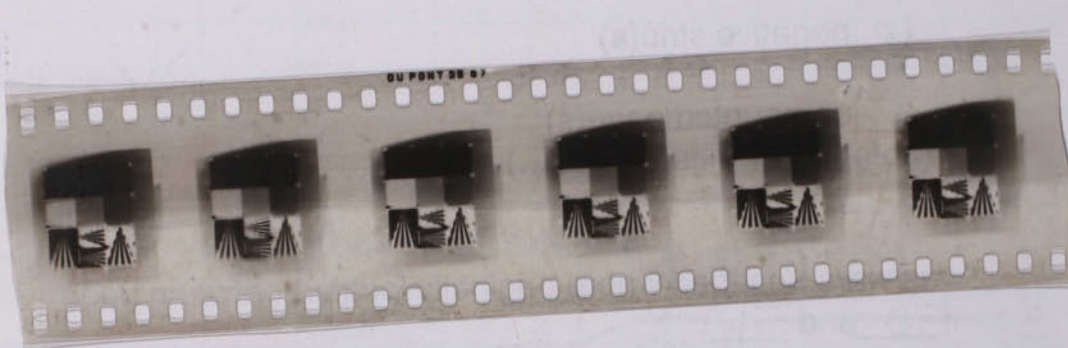
____unmounted photograph(s)

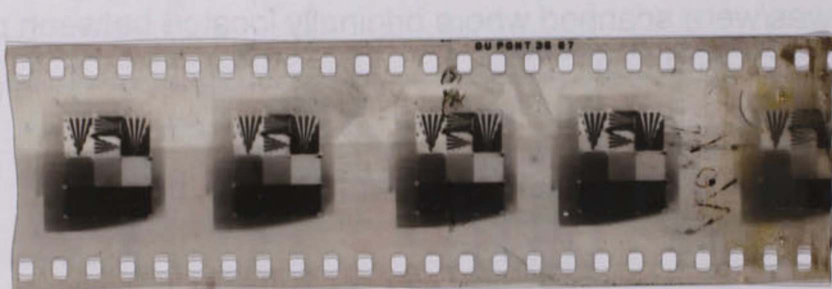
6 negative strip(s)

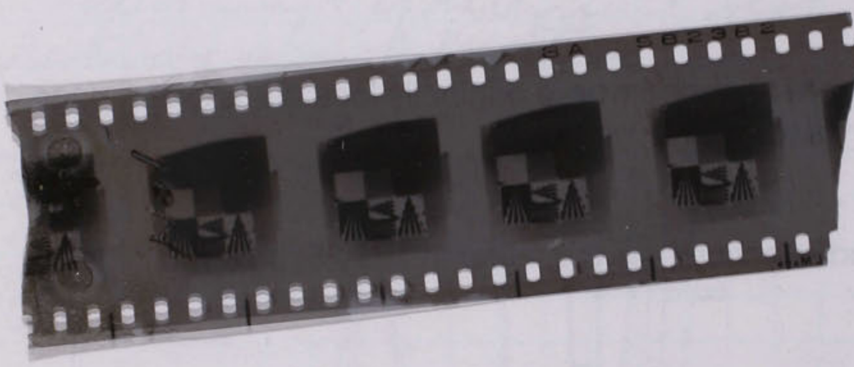
____unmounted page(s)
(notes, drawings, letters ...)

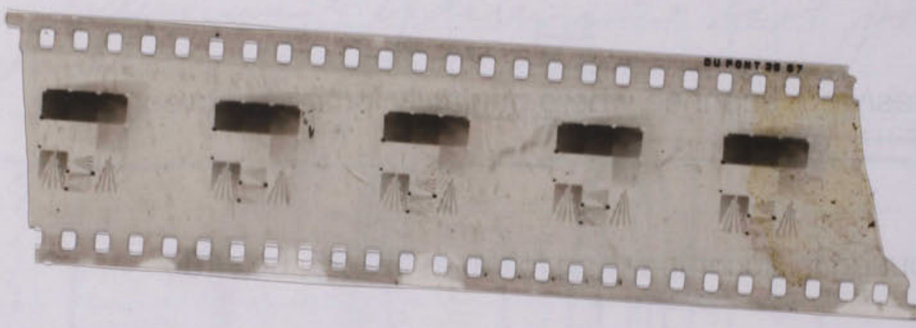
was/were scanned where originally located between page 70 and 71.

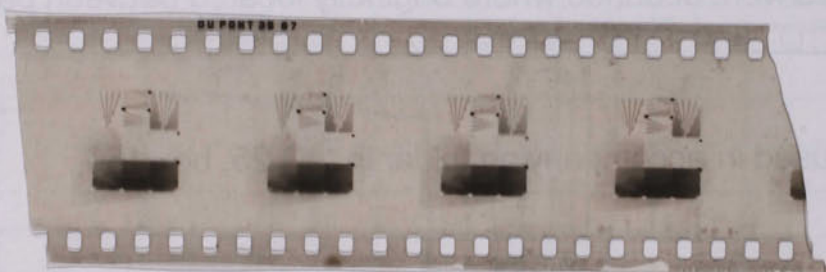
Item now housed in accompanying folder in MC 25, box 166

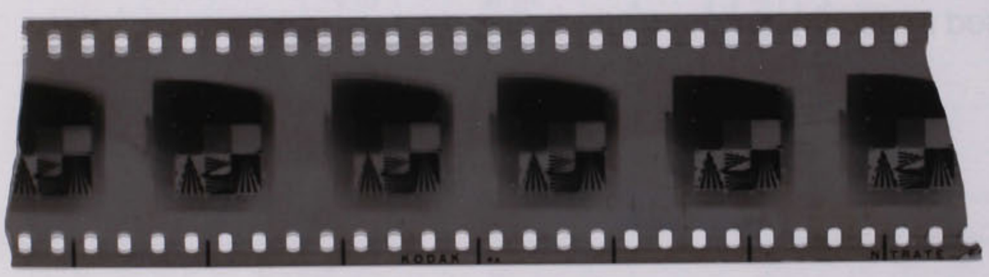




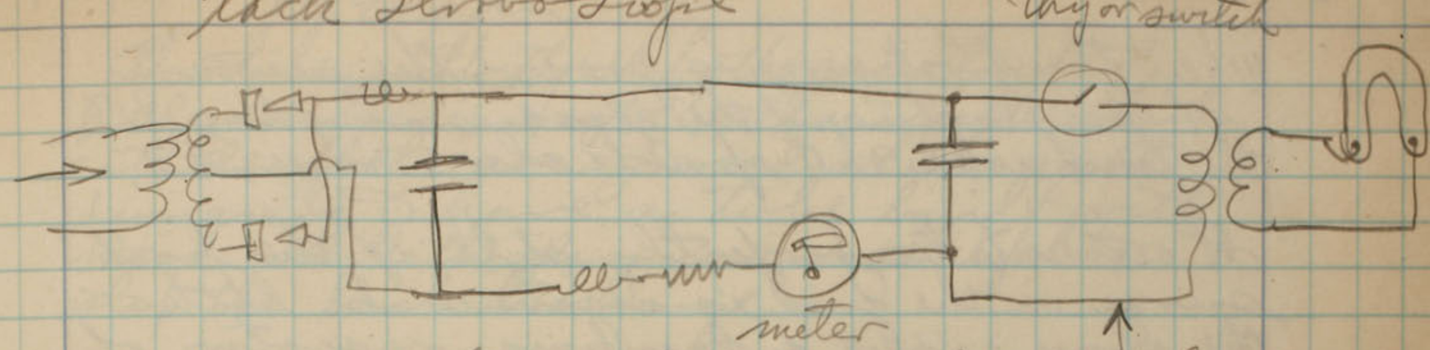







KODAK
NITRATE

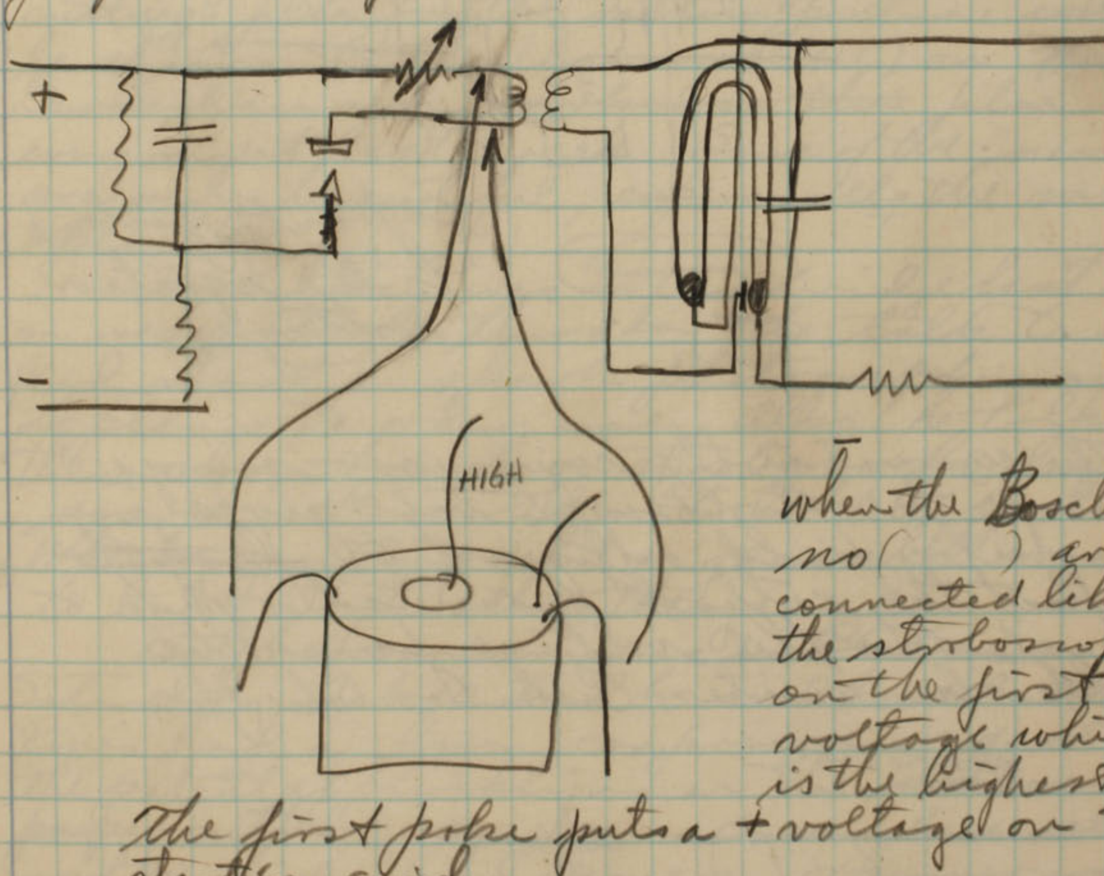
Tach Stroboscope



the meter could also be put in this part of the circuit

Feb. 7, 1934.

Experiment to determine best polarity of operating spark exciter.



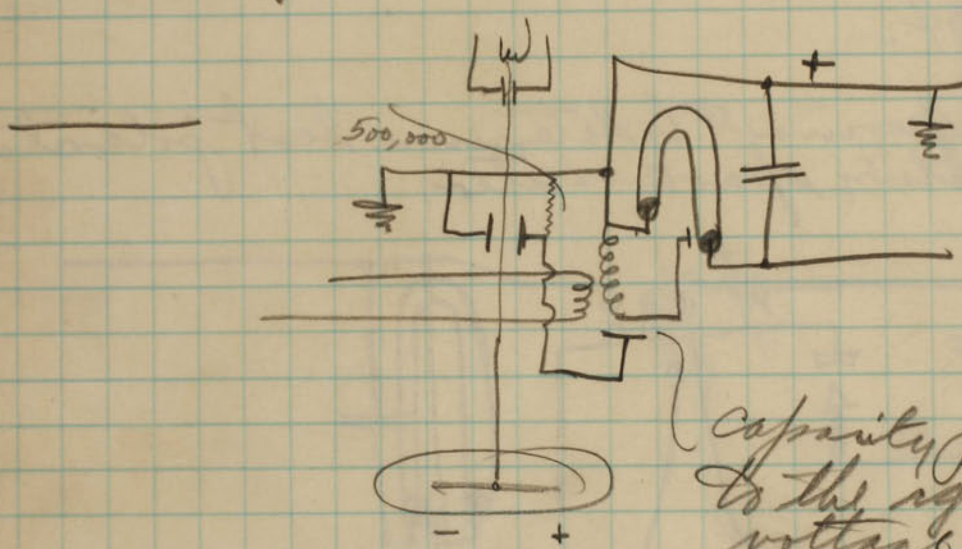
when the Bosch coils no(   ) are connected like this the stroboscope kicks on the first rise of voltage which also is the highest voltage.

the first pulse puts a + voltage on the starting grid.

Feb. 7, 1934.

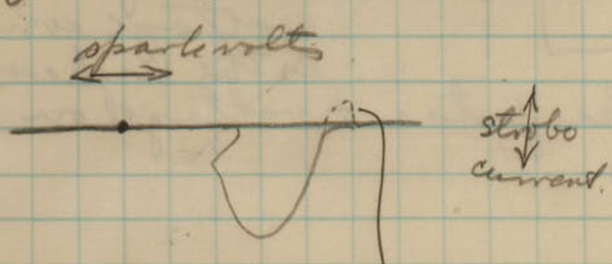
When the first surge is positive the mercury at the junction of the glass is shifting all the time when the spark alone is excited.

It seems to be perfectly still if the first surge on the grid is negative. In both the above cases a damping resistor of 75,000 ohms (three 25000 thyrite red devils in series). The polarity of the first surge is determined by an oscillograph (cathode ray) as below.



capacity pickup to the ignitron voltage.

The current in the condenser surge through the stroboscope tube gives a magnetic field sufficient to ~~flash the~~ deflect the cathode beam at right angles to the voltage from the spark exciter. Pictures like this.



a reverse current flows when a cathode spot is present on the anode pool.

Feb 7. 1934. H.E. Edgerton.

The tubes with Hg at both ends tend to hold over because of the ease with which cathode spots are formed at the anode. I am going to have a tube built with mica inside the glass in an attempt to stop the back discharge.

Tonight I tried an external metalic connection around the glass and electrically connected to the anode. It apparently made no difference in the operation of the tube as far as reversal is concerned.

Feb 11 1934.

I spent part of today writing titles and cutting film for the motion picture which is to be shown to the Alumni (M.I.T.) on ~~F~~ Feb 17th. Germeshausen worked on this film nearly every night last week. Some of the new shots are very beautiful, especially the milk splashes.

Mr. H. L. Day was in Cambridge last week on wednesday or thursday? to talk to Gen. Rad. about a spark photographic outfit. He plans to order one. Also he talked to them about a big stroboscope lighting source. He wanted us to take a picture of Whisky pouring into a glass but we were to busy with other things.

Ralph Hammar was in Boston on Saturday Feb 10 and he and I and Mr Rines had a long conference regarding the patent applications on the stroboscope, paper cutter synchronous machine relay, and the high speed camera. Hammer was out to my home for dinner and we looked over my note books for dates to establish priority over the G E Cockerell patent.

Feb 13 1934

H.E. Edgerton.

Spent most of day collecting evidence and getting affidavits off to Layton Northrup and Wife of Winnetka, Illinois regarding the civil action of Mr. Elwood A. Howe.

Feb 14. 1934 Delta transformers in spark apparatus

6305 A Plate transformer 5500 V
6765 Fil transformer 2 - 2.5V

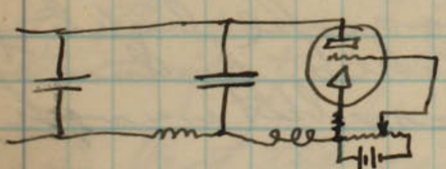
Transformers in 10-KW power unit.

6567 Plate trans. 3 phase.
6568 Fil trans 4 sep winding.
6842 choke. Too small in henries.

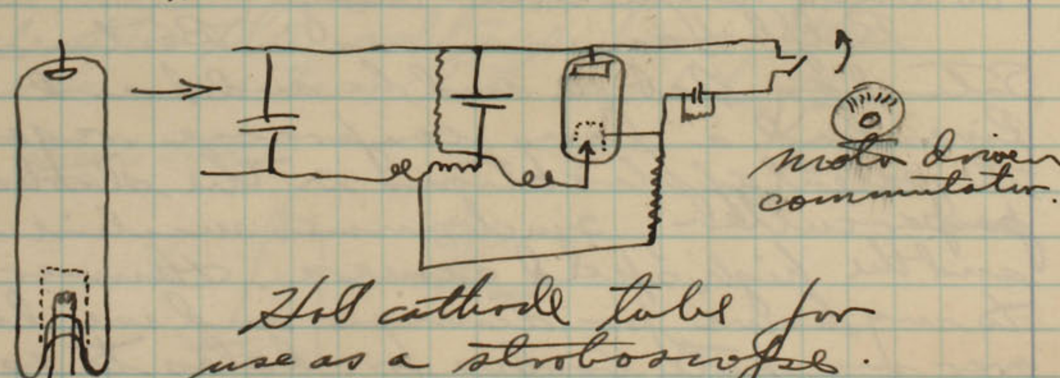
Feb. 19, 1934.

Showed H-S. movies to the M.I.T Alumni on last Saturday. Feb 17.

Made arrangements today for moving into my new laboratory in 10-213 and the adjoining room.



oscillator, for stroboscope



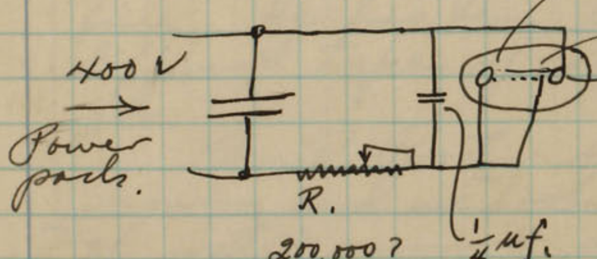
Hot cathode tube for use as a stroboscope.

Feb. 21, 1934
HE Edgerton.

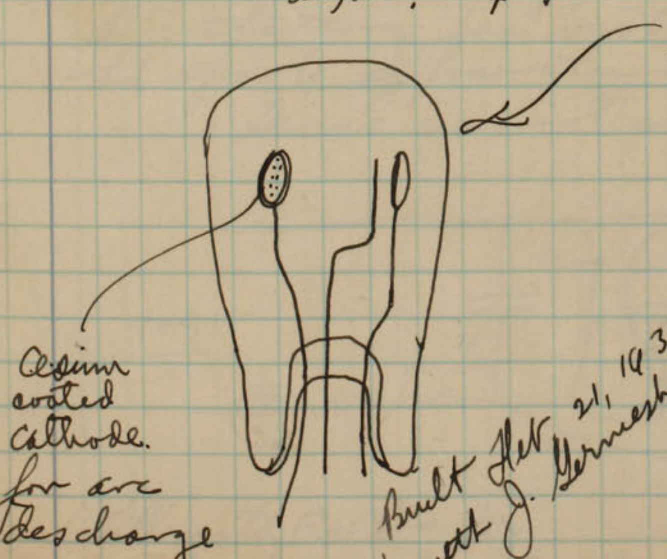
I was supposed to go to Providence yesterday night to talk to the Engineers club but postponed the meeting because of the blizzard.

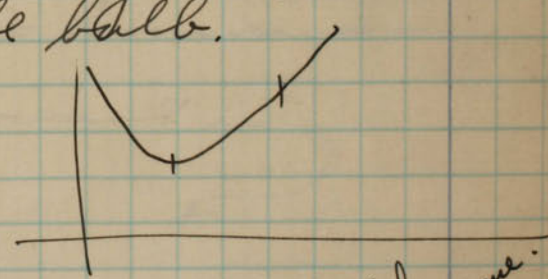
Today I started to clean up the dark room on the second floor and discussed changes with the B&P men.

Germeshausen got a small stroboscope tube today that looks encouraging as a tachometer. It has a cesium coated cathode that snaps into an arc when the glow starts. A small auxilliary ~~anode~~ cathode close to the anode starts the discharge. The tubes tried today had 6 mm of neon in them. The discharge was a column about 1/4 of an inch in diameter. The oscillations were fairly constant, sufficiently good to act as a ~~stro~~ tachometers.



The actual tube was in a stem and in a regular radio tube bulb.



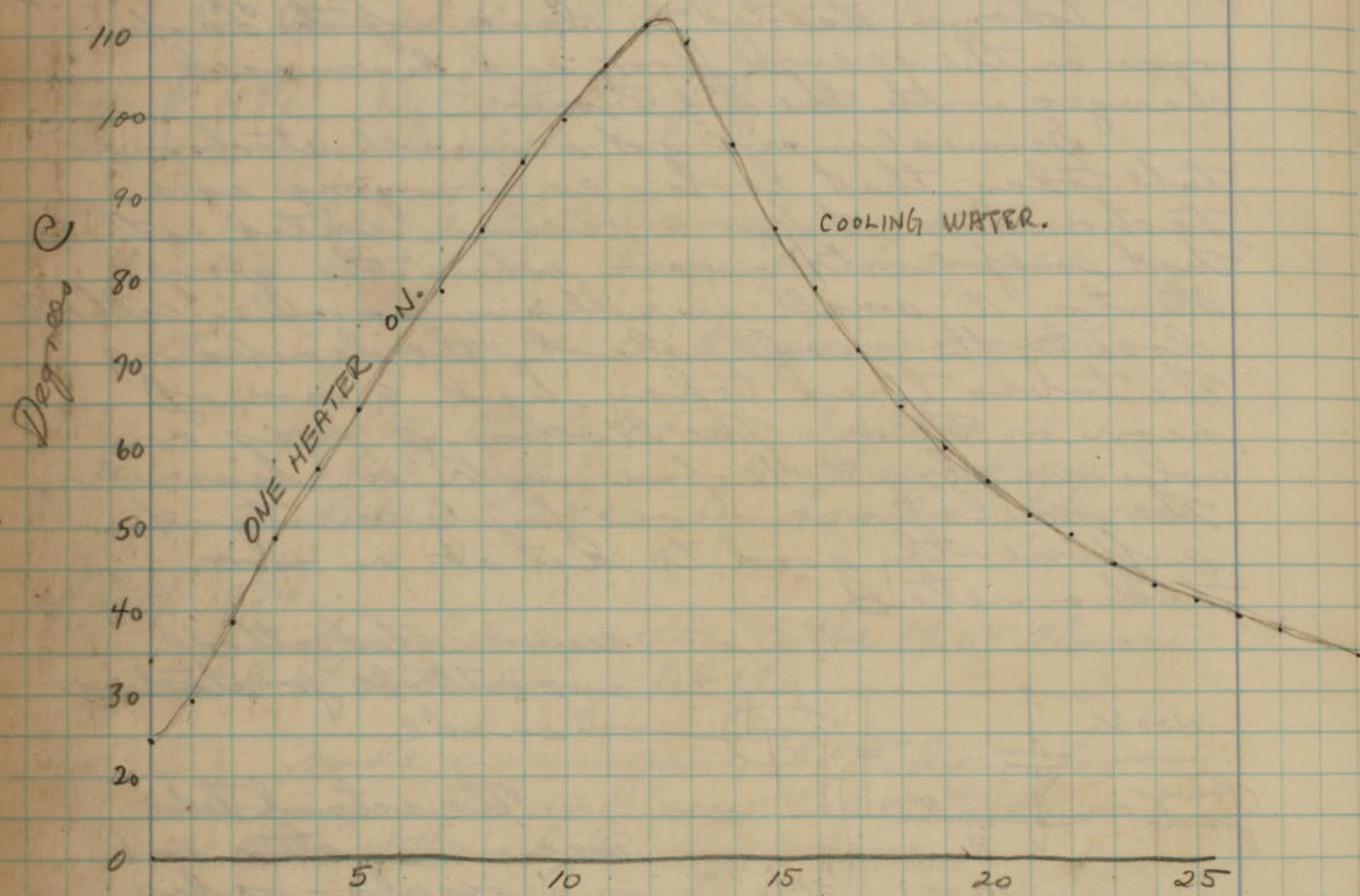


Built Feb. 21, 1934
Kenneth J. Germeshausen

This was explained and demonstrated to me.
T. S. Gray
Feb. 21, 1934.

Feb 23, 1934
H E Edgerton

Time-temp curve on apparatus
for testing thyratrons.



March 3, 1934.
H. E. Edgerton.

Moved part of the laboratory equipment into room 10-213 and the adjoining room which is to be our new lab.

On Saturday I showed the strobo and the roll of movies ~~to the~~ some High school students.

Germs made more tubes during the week. We took one over to G.R. and gave it to Wilkins together with a circuit for him to try out.

I built a krimped cathode with Ba and Sr. Carbonate in it. Germs tested it and said that it tended to hold over.

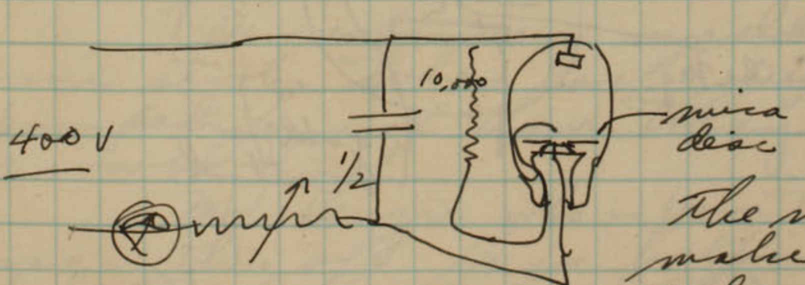
March 9 1934.

Waldead was here yesterday and talked about the problems of arc welding. We hope to take some motion pictures of the arc with the Eastman camera.

Germs tube development is coming fine. He has been building tubes with different types of cathodes. Sodium, Caesium etc.

Mr. R. Proctor was here yesterday morning and we took some photographs of water running, a swaying bulb, and a rotating fan with his camera using the spark apparatus.

Germs circuit at present is:



The mica disc makes the arc go down through the hole.

Pills with CsCl + Mg liberate Cs when bombarded.

Also NaCl + Pb liberate sodium which acts as a cathode the same as the Cs.

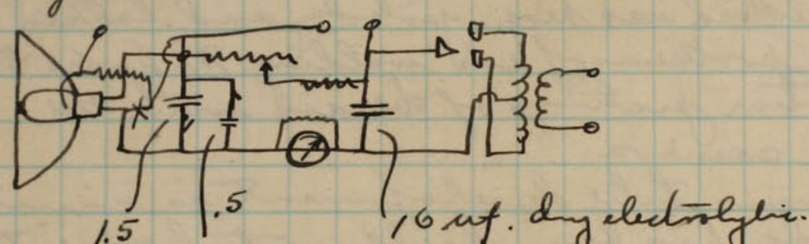
March 12 1934
H.E. Edgerton

Zworykin of the R.C.A. here today to give a lecture on television. Also to be here tomorrow.

Prof. Swarty of the textile department was here today with a group of visitors.

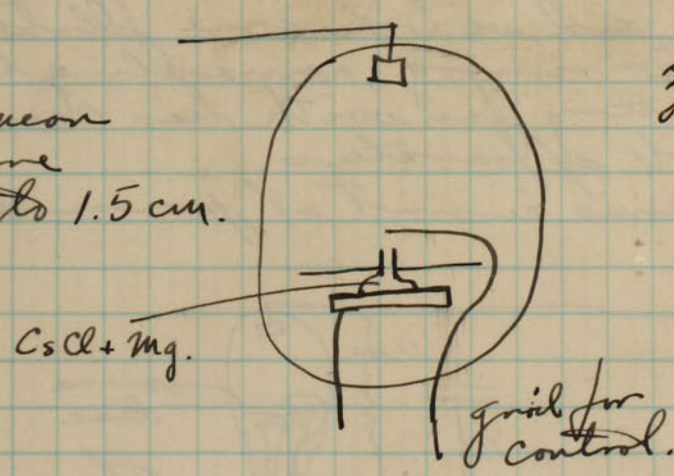
Discussed with Germeshausen the circuits and the form of the neon strobotach which G.R. are to build. The small synchronous motor for calibration may be put in the reflector. Terminals will be brought out for oscillator control and for contactor trip.

Experiment shows that 350 volts with a 16 uf electrolytic dry condenser seems to be able to filter the supply enough at 22 ma.



Scale span changed by capacity switch from .5 to 2 uf.

Filled with neon at a pressure of about 1 to 1.5 cm.

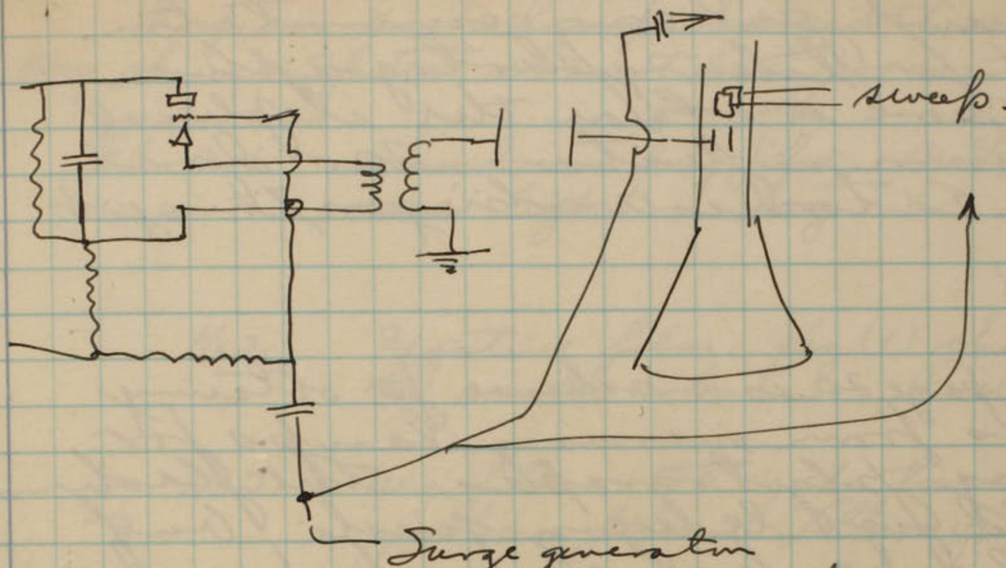


3600 per min.
22 ma.
1½ uf. capacity.

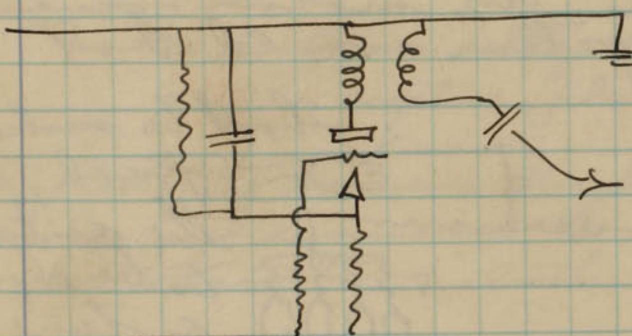
March 13, 1934

Moved Cathode Ray oscillograph up to 10-211A George Oscillograph which we obtained last year. I am going to use it to study the oscillations of the voltage of spark coils for driving the stroboscope lamps.

Mar 13 cont.



Surge generator for tripping sweep, anode, and thyratron.



Circuits for testing the Sparks coils.

March 14 1934. Herbert Grier and Roland Eaton put up a film drying rack today in the lab. It is 3 ft in diam and about six feet long.

Germeshausen made seven neon strobo tubes last night and pumped four of them today. They seem to work fine.

MacKenzie who is here this term was in this aft. He is helping with the high speed photographs.

I got out our old camera which was ~~built~~ used last ~~summer~~ year. It will be useful when fixed up.

Tested the General Radio camera

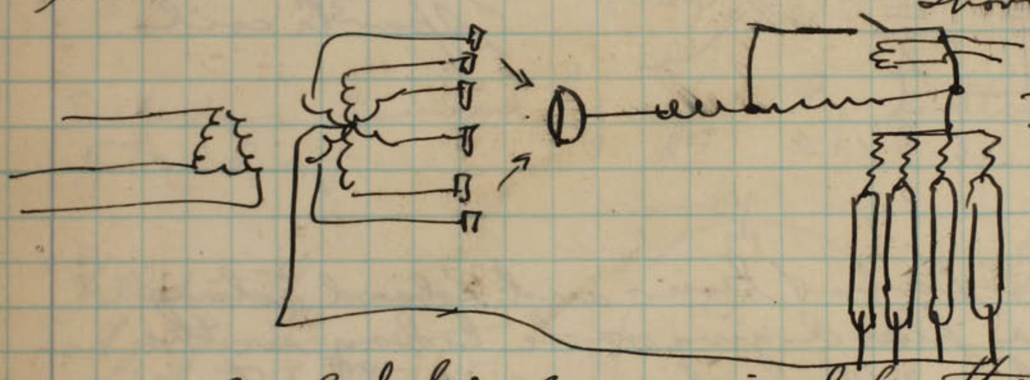
Mar 14 1934 cont.

today and put our commutator on it for taking photographs.
More work on the elliptical aluminum reflectors was done today. Eaton is working on this job.

March 14 1934
H. E. Edgerton

On page 20 is a scheme for obtaining flashes from mercury lamps for taking photographs. The flashes would not be very quick but would be fast enough for ordinary photographic work such as in studios.

If there is a supply of three phase power capable of supplying surges of power, the motor-generator energy storage system would not be needed.



The trip could be energized by the shutter.

Another method would be to use grids on the anodes of the polyphase rectifier tube whereby control is effected by varying the phase.

March 15 1934 Set up high-speed camera using two lamp houses in elliptical reflectors for taking movies of typewriters for Prof. Norton.

March 15 1934
H. E. Edgerton
K. J. Germeshausen
H. Grier
R. Eaton.

2 uf on each lamp charged through 800 ohms. Speed about 600 per second.

Film no. 1. Sound recording film. Not sufficient ~~con~~ light on key Y. L.C. Smith 10

No 2. Negative film. Key (Y) chaulked to make whiter. Pictures ok. L C Smith 10

No 3. neg film. 60 cycle timing wave put on film. Letter y. L C Smith 10

No. 4. Neg film 60 cycle timing wave Letter y. Remington #6.

March 16, 1934

No. 5. Special ~~type~~writer key. Y. 600 p.s. negative film.

Mr. Root of the Danvers Bleachery company was here today and discussed the use of the stroboscope for straightening cloth in a tenter frame.

Mr. Dana Burks was here yesterday and discussed ~~the~~ same problem. He is in Providence with the Kendall Co.

March 17, 1934. Lab in morning. Took some pictures of arc welding in Bullocks lab. in the M.E Dept.

Germeshausen is still working on the design of his neon tubes. He built ~~four~~ the other day with a 1/8" diam chimney about 3/8" high. With 20 ma. continuous load it gave trouble in two hours. The breakdown voltage was greatly reduced because the caesium apparently came out of the pill and condensed on the sides of the tube. This small metal tube had be oxidized before the pill was bombarded.

Mar 17 1934
H E Edgerton

Film No 3. 1/200 f 32? 200 ± a Plenachrome.
No 4 1/200 f 16 "

Moving Picture film 35 mm positive film

Shot No		Filter No	Stop	
1	punch.	1/4" glass No filter	f.22	2/4
2		" K2 8	f 22	1/4
3		" 23	f "	
4		" 70	"	
5		" 87	"	
6		" x neut gray.	"	
7		" " " darker.	"	1 1/2
8		" " " " yet	"	1
9		" 89	"	1
10		" Green Goggle glass.	"	1
11		" No 10 Weld Service Co	"	1
12		" Airco Goggle Spec		

Note #4 Filter No 70 looks promising.
#6 "
#7 some streamers.

March 19. 1934
H E Edgerton.

Acceleration test on G.R. Camera.
↓ 220 ac on motor. Commutator on
70 turns on the take up reel

t	holes	
0	6	f.p.s.
1/60	7	6.57
	9	8.35
	10	9.38
	11	10.3
6/60	12	11.2
	13	12.2
	14	13.1
	15	14.1
	16	15
	17	15.9
.2	19	17.8
	20	18.7
·	21	19.7
·	22	20.6
	24	22.5
~~.3~~	25	?
3	26	24.4
·	27	
	28	
	29	
	30	
	31	
.4	32	30
	34	
	35	
	36	
	37	
·	37.5	
.5	38.5	36.5
	40	
	41	
	41.5	
·	42.5	
	43	
.6	44	41.2
	45	
	46	
	47	
	48	

t	h	
	49	
.7	49.5	46.3
	50	
	51	
	52	
	53	
	53.5	
.8	54	50.5
	55	
	56	
	56.5	
	57.5	
	58	
.9	59	55.3
	59.5	
	60.	
	61.	
·	62.	
·	62	
1.0	63	59.
	64	
	64.5	
	65	
	66	
·	66	
1.1	67	62.7
	67.5	
	68.	
	68.5	
	69.	
	69.5	
1.2	70.5	66
	71	
	71.5	
	72.	
	72.5	
	73.	
1.3	73.5	69
	74.	1110
	-	f.P.S.

220 DC on the takeup motor. Same as above.

~~50 turns on the take up.~~

t.	holes.	
0	9	
1/60	11	
	15	
	17	
	20	
	23	
.1	26	24.4
·	29	
·	31	
	34	
	36	
	38	
.2	40	37.5
	43	
	44.5	
	46.	
	49	
	50	
.3	52	48.7
	54	
	55.5	
	57.	
	59.	
	60	
.4	62	58
	63	
	65	
	66	
	67.5	
	69.	
.5	70	65.5
	71.5	
	73	
	74	
	75	
	76	
.6	77	72

78
79
splice went thru o.k.

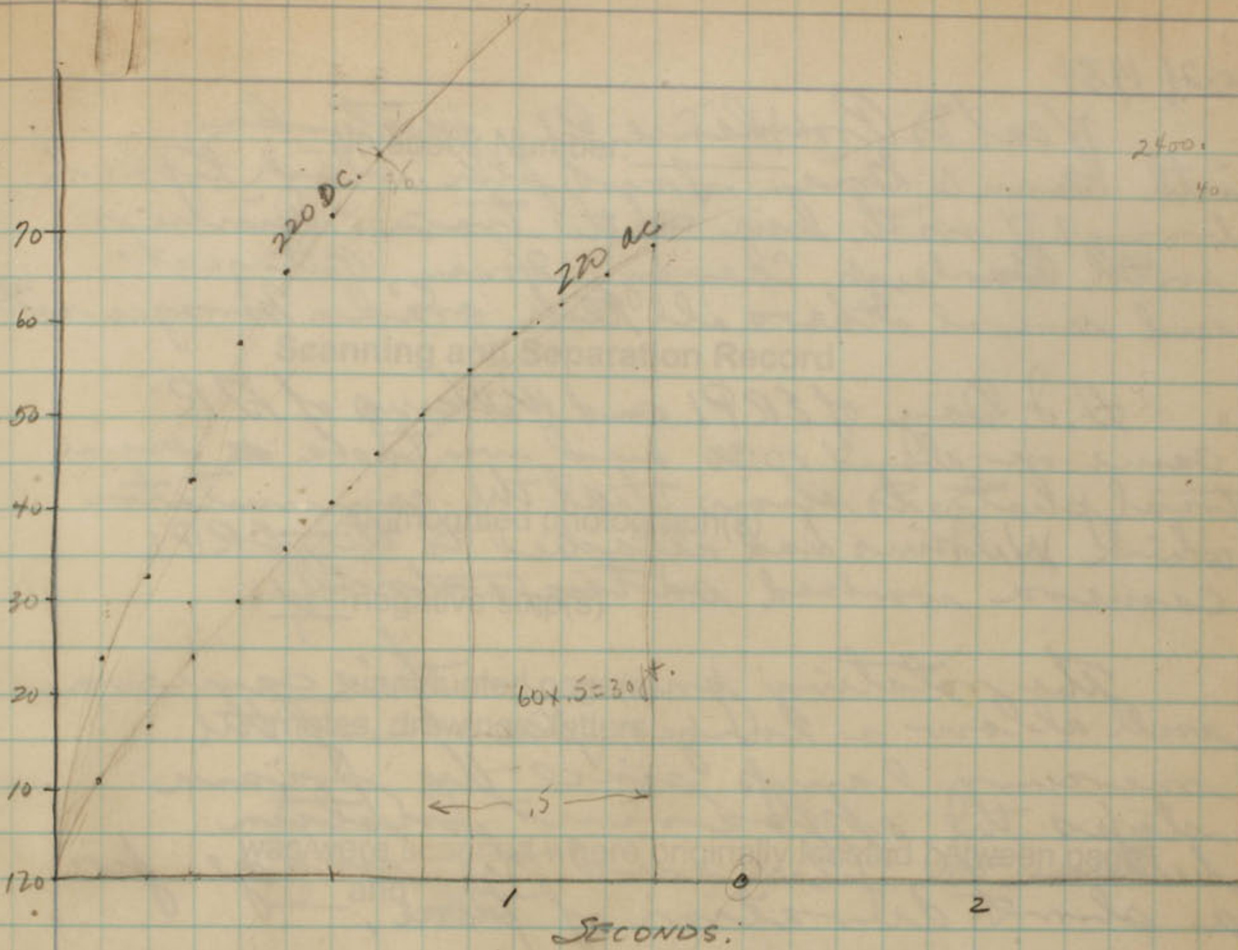
220 ac on takeup
220 3phase 1/4 hp 1800 Ind.
with a 1:1 pulley.

t	holes.	f.p.s
0	0	
1/60	6	5.63
	9	8.45
	11	10.3
	13	12.2
	15	14.1
0.1	17	15.9
	19	17.8
	21	19.7
	22	20.6
	25	23.4
	27	25.3
0.2	29	27.2
	31	29.1
	33	31
	35	33
	37	34.7
	39	
0.3	40	37.5
	40	
	41	38.5
	41	
	41	
	41	
0.4	41	
	41.5	
	41	
0.5	41	
0.6	41	
.7	41	
.8	41	
.9	40	
1.0	39.5	
1.1	39.	
1.2	39	
1.3	38	
1.4	37	
1.5	36.5 end.	

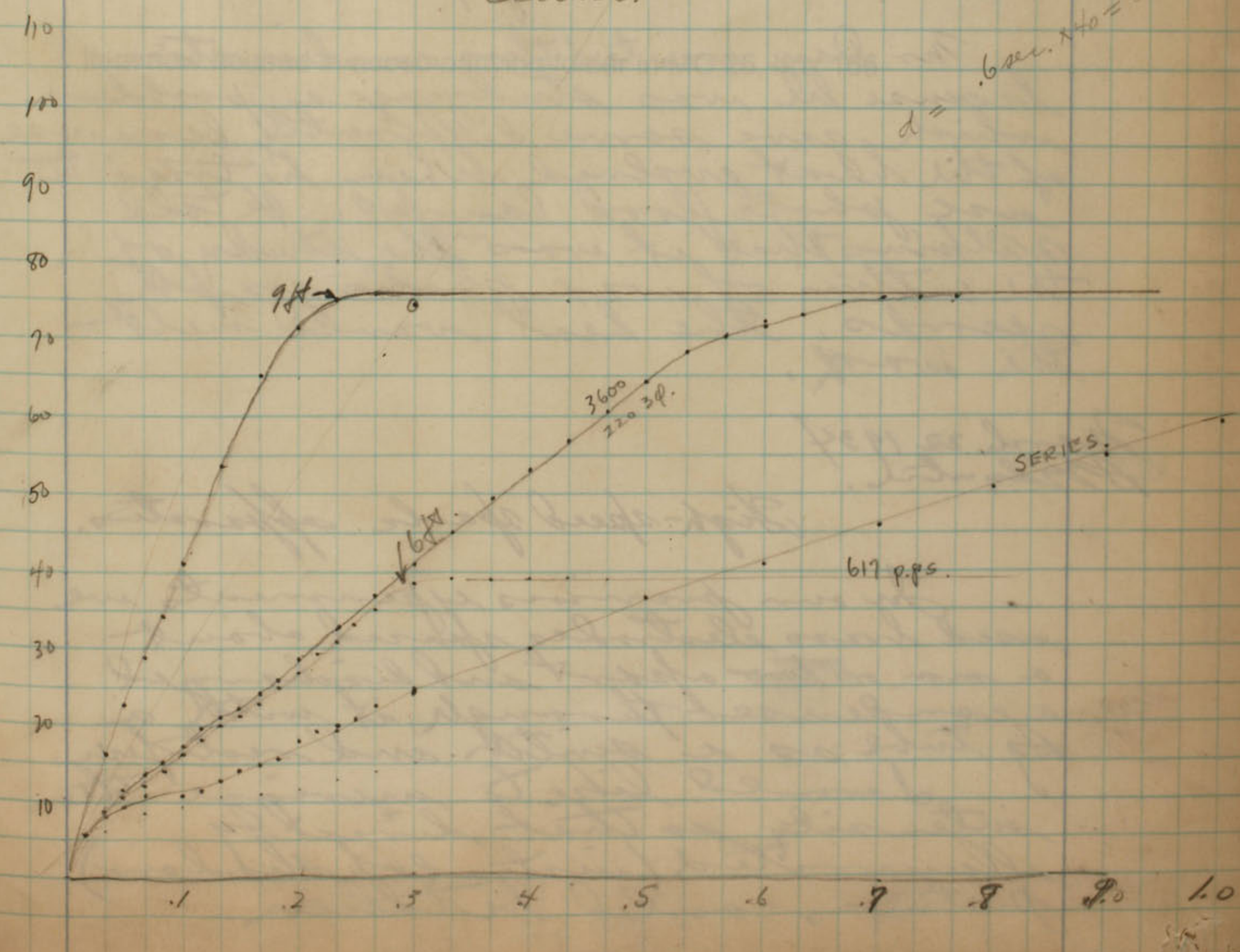
220 ac on takeup
220 3φ ac on main drive
3600 Ind 1:1.

t.	holes.	
0		
1/60	7	6.5
	10	9.4
	12	11.
	14	13
	16	15
.2	18	17
	20	19
	21.5	21
	23.5	22
	26.	24
	28.	26
.3	30	28
	33	
	35	33
	37	
	39	37
	41	
.4	44	41
	46	
	48	45
	50	
	52	49
	55	
.5	56.5	53
	59	
	60.5	56.5
	63	
	65	61
	67	
.6	68.5	64
	70	
	72	67.5
	73	
	75	70
	76	
.7	77	72
	78	

	79	74
	79	
	80	75
	80	
.8	80.5	75
	81.	
	80.5	75
	81	
	81	76
	80.5	
.9	80	
	80	
	79	
	79	
	79	
	78	
1.	78	
	77.5	
	77.	
	77	
	76.5	
	76	
1.1	76	
	75	



220 DC.
220 ac
2400.
40
60 x .5 = 30 ft.
.5
70
60
50
40
30
20
10
1
2
SECONDS.



d = .6 sec. x 40 = 30 ft.
9 ft
16 ft
3600
220 3 ph.
SERIES.
617 p.p.s.
120
110
100
90
80
70
60
50
40
30
20
10
.1
.2
.3
.4
.5
.6
.7
.8
.9
1.0

Mar. 21, 1933

Went to Providence R.I. yesterday with Germ & Grier. Forgot film which Germeshausen brought with him on the train. Dinner with Burleigh, Cheney, Hovey, Pettingast?, and several others all Tech. grads. Narragansett Hotel.

H. I. Day of ERPI and Wilkins of BR came over about 10:30 and we took several trial photos to show that the commutator which Wilkins had attached to the ERPI camera worked satisfactorily.

The rotating prism in this camera will allow a longer flash of the mercury lamp since the prism stops the apparent motion between the film and the image for a short duration of time.

Mr. Day wanted this combination because he was studying a problem which gave some difficulty because of the heat evolved when he tried to use photoflood lamps. He told Wilkins that it was the study of the cutting of wax phonograph records. The heat would melt the wax.

March 22 1934
H.E. Edgerton.

High-speed spark apparatus.

In our previous experiments we used brass electrodes spaced about a mm or two apart and discharged a condenser through it with a Hg tube as a switch and rectifier.

I would like to increase the intensity so that directly illuminated (instead of shadow) pictures could be taken.

Notebook Number: T-4

Scanning and Separation Record

____unmounted photograph(s)

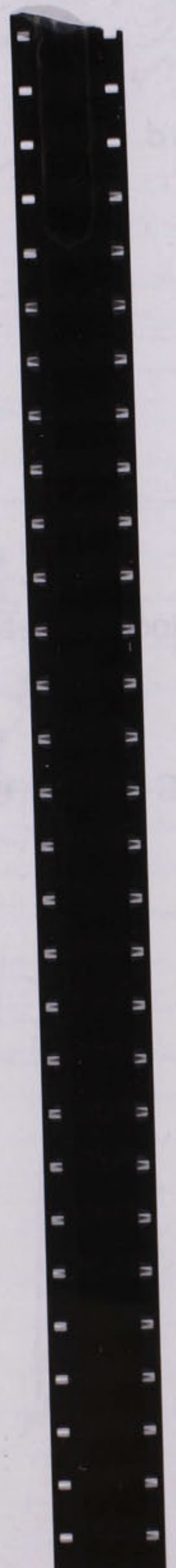
1 negative strip(s)

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

was/were scanned where originally located between page 86 and 87.

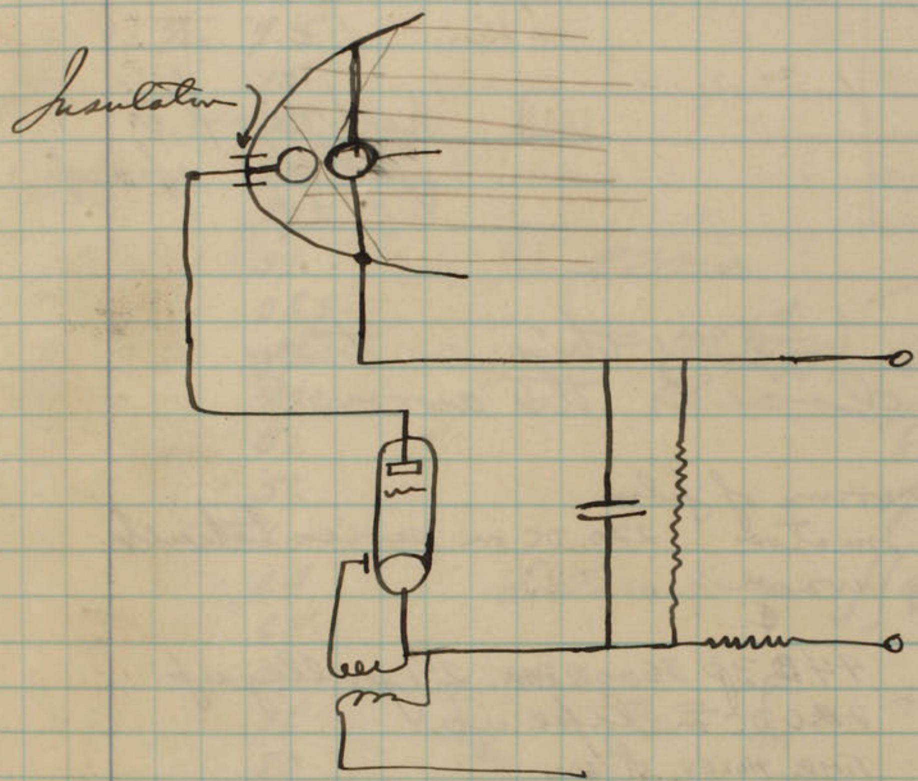
Item now housed in accompanying folder in MC 25, box 166

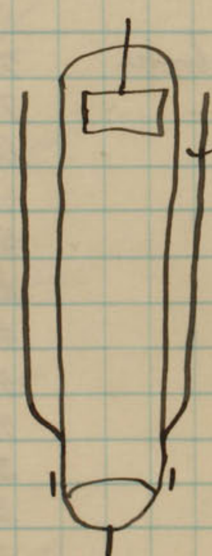
trip air.



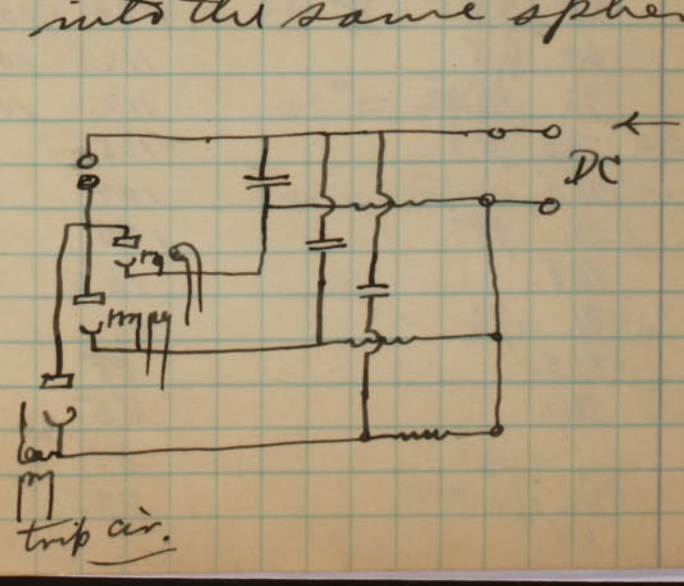
trip cir.

The electrodes might be aluminum spheres which would carry away the heat and not get hot for the duration of the sparking time. A reflector could get most of the light.





Several tubes to discharge into the same spheres.



March 23 1934
~~HE Edgerton~~.

Taylor brought in a bow and arrow today. We plan to take some motion picture shots ~~to~~ get the acceleration time curve of the arrow as it leaves the bow.

half round to fit the spark coil.

Build some like this so they can be put close to the arrow.

Acceleration run of film
~~440~~ 3 phase on motor   220 DC on series takeup.
60 cycle timing wave.

Time	holes	ft/sec
0		
1/60	15?	14
2/60	17.5	16.4
	24.	22.5
	30.5	28.6
	37.	34.7
~~.1~~	44.	41.2
	51.	48
	57	53.5
	63	59
	69	65
	73.	68.5
0.2	76.5	71.8
	78.5	
	80.	75
	80.8	
	81.	76
	81.5-	
.3	81.0	

33 60th of a sec.
(75.)

4) 354.
Σ 16) 5675.
48
87
80
75

440 3p 3600 R.P.M. 2:1 pulley up.
220 DC on take up.

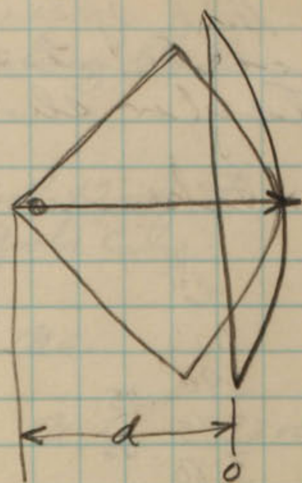
TIME	HOLES	ft/sec.	
141	126	end brake	74
138	122		70
135	120		66
132	117		62.5
128	113		59.
124	110		55
120	106		51
116.5	103		47.
112.	100		43
108			38.5
104			34.
100			29.
95.5			25.5
91			
88			
85			
81			
77.5			

Ditto.

440 3φ 3600 RPM motor
2:1 stepup.
220 DC on takeup.

0	
1/60	9.5
	15
	20
	25
	29.5
.1	34.
	38.5
	43.
	47
	52
	56
.2	60
	64
	68
	72
	76
	80
.3	84
	88
	92
	96.5
	101.
	105
.4	109.5
	114
	118.5
	123.
	127
	131
.5	134.5

broke film.



this equation only holds from d = 2 to d = 0.

$F = ma$

$F = 48\left(\frac{d}{2}\right)$ d measured in ft. (Emperical equation of the force on the arrow as a function of distance).

$$\text{distance} = \iint a\,dt^2$$

$$a = \frac{F}{m} = 48\left(\frac{d}{2}\right)\frac{1}{m}.$$

$$d = \iint\left(\frac{24}{m}\right)d\,dt^2.$$

Energy. $\frac{1}{2}mv^2 = \int_0^d F\,dx$

$$= \int_0^d \frac{24}{m}\,d\,dx = \frac{24}{m}\frac{d^2}{2} = \frac{1}{2}mv^2$$

$$v^2 = 24\frac{d^2}{m^2}$$

$$v = \sqrt{24}\,\frac{d}{m} = \frac{2}{\frac{1}{30}}\,4.9$$

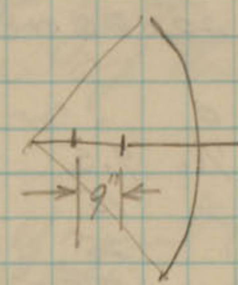
$$= \frac{294.}{32.2} = 91.3$$

March 26 1934
H E Edgerton.

High speed motion pictures of the acceleration of a bow and arrow.
Taylor shot the arrow

Bow taken as a reference.

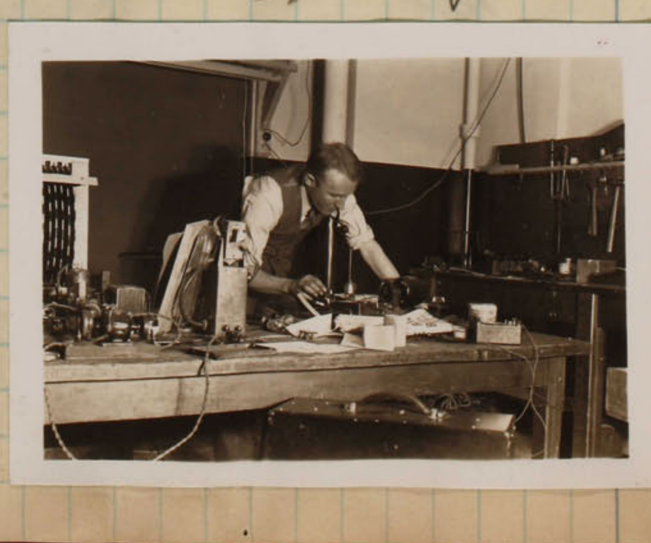
9" = 1.75"
" on film



	t	d			
	0				
	1/1020	3.90	.05		
	3/1020	3.85	.05		
		3.80	.10		
		3.70	.14		
		3.56	.11		
		3.45	.20		
		3.25	.15		
		3.10	35		
		2.85	15		
9"=1.75		2.70	30		
		2.40	.20		
		2.2	.30		
		1.9	.25		
		1.65	.30		
String in contact		1.35	.30		
		1.05	.30		
		.75	.35		
String leaves arrow		.4	.30	1.3	3
		.1		1.	35
				.65	40
				.25	

Second shot taken. Analyzed by Taylor.

K. J. Germeshausen experimenting with neon stroboscope tubes



March 30 1934
H.E. Edgerton.

Pictures of Gillette Razors breaking blades.

Razor of Ch. Hoskins
(11-20-29) 55 West 42nd St
New York City.

No. 1. Underexposed 1200 p.s. N.G.

No. 2. Film ~~for~~ broke in camera N.G. 1200

No. 3 Blade broke too quick N.G. 1200

No. 4. O.k. 1200 p.s.

No "

March 30, 1934. evening.
R.D. Eaton.
High speed movies of Big Razor.
at 1200

No 5. showing both corners

No. 6 " one corner break

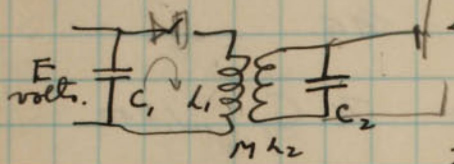
Ordinary movies of the big razor. two scenes.

March 31, 1934
H.E. Edgerton & Germeshausen.
Movie scenes for Gillette picture
Prof. C.L. Norton posed for one of the
pictures showing dropping of a blade.

April 4. 1934.
H. E. Edgerton.

Tuned spark coil circuits.

There should be a best value for the primary condenser for each spark coil. The circuit is approx as shown



Differential equations.

$$\frac{i_1}{pC_1} + pL_1 i_1 + pM i_2 = 0 \qquad (1)$$

$$\frac{i_2}{pC_2} + pL_2 i_2 + pM i_1 = 0 \qquad (2)$$

from 2.

$$i_1 = \frac{-\left(\frac{1}{pC_2} + pL_2\right) i_2}{pM} = -\left(\frac{1}{p^2 C_2 M} + \frac{L_2}{M}\right) i_2$$

put in (1.)

$$\left(\frac{1}{pC_1} + pL_1\right) i_1 + pM i_2 = 0$$

$$-\left(\frac{1}{pC_1} + pL_1\right)\left(\frac{1}{p^2 C_2 M} + \frac{L_2}{M}\right) i_2 + pM i_2 = 0.$$

$$\frac{1}{p^3 C_1 C_2 M} + \frac{pL_1 L_2}{M} + \frac{L_1}{pC_2 M} + \frac{L_2}{pC_1 M} - pM = 0$$

mult by p^3.

$$\frac{1}{C_1 C_2 M} + p^4 \frac{L_1 L_2}{M} + \frac{L_1 p^2}{C_2 M} + \frac{L_2 p^2}{C_1 M} - p^4 M = 0$$

$$p^4\left(\frac{L_1 L_2}{M} - M\right) + p^2\left(\frac{L_1}{C_2 M} + \frac{L_2}{C_1 M}\right) + \frac{1}{C_1 C_2 M} = 0.$$

$$p^4\left(\frac{L_1 L_2}{M^2} - 1\right) + p^2\left(\frac{L_1}{C_2 M^2} + \frac{L_2}{C_1 M^2}\right) + \frac{1}{C_1 C_2 M^2} = 0.$$

Campbell & Foster

With initial chg on C_1 of E volts.

$$\left(L_1 p + \frac{1}{C_1 p}\right) i_1 + M p i_2 = E = \frac{Q_0}{C_1}$$

$$M p i_1 \quad + \left(L_2 p + \frac{1}{p C_2}\right) i_2 = 0.$$

Solving for i_2

$$i_2 = \frac{Mp}{\left(L_1 p + \frac{1}{C_1 p}\right)\left(L_2 p + \frac{1}{p C_2}\right) - M^2 p^2} \frac{Q_0}{C_1}$$

$$q_2 = \frac{1}{p} i_2. \qquad e_{c_2} = \frac{q_2}{C_2} = \frac{1}{C_2 p} \frac{Mp}{(\sim\sim) - M^2 p^2} \frac{Q}{C_1}$$

~~$$e_{c_2} = \frac{M}{C_1 C_2} Q_0 \frac{p^2}{(L_1 C_1 L_2 C_2 - M^2) p^4 + (L_1 C_1 + L_2 C_2) p^2 + 1}$$~~

$$e_{c_2} = \frac{Q_0 M p^2}{(L_1 C_1 p^2 + 1)(L_2 C_2 p^2 + 1) - M^2 p^4 C_1 C_2}$$

$$e_{c_2} = M Q_0 \frac{p^2}{p^4 (L_1 L_2 C_1 C_2 - M^2 C_1 C_2) + p^2 (L_1 C_1 + L_2 C_2) + 1.}$$

$$\underline{e_{c_2}} = \frac{M Q_0}{(L_1 L_2 - M^2) C_1 C_2} \left[\frac{p^2}{(p^2 + a^2)(p^2 + b^2)} \right] 1$$

$$\frac{p^2}{p^4 + \frac{(L_1 C_1 + C_2 L_2)}{(L_1 L_2 C_1 C_2 - C_1 C_2 M^2)} p^2 + 1}$$

$$\frac{p^2}{(p^2 + a^2)(p^2 + b^2)} \quad \text{where } a^2 = \frac{L_1}{C_2 (L_1 L_2 - M^2)}$$

$$b^2 = \frac{L_2}{C_1 (L_1 L_2 - M^2)}$$

$$\frac{p^2}{\left(p^2 + \frac{L_1 C_1}{C_1 C_2 (L_1 L_2 - M^2)}\right)\left(p^2 + \frac{L_2 C_2}{C_1 C_2 (\sim\sim)}\right)}$$

Evaluate $\frac{p^2}{(p^2+a^2)(p^2+b^2)} 1 = K_1 \frac{1}{p^2+a^2} + K_2 \frac{1}{p^2+a^2}$.

to get k_1 mult by (p^2+a^2)

$$\frac{p^2 (p^2+a^2)}{(p^2+a^2)(p^2+b^2)} = k_1 + k_2 \frac{p^2+a^2}{p^2+b^2}$$

Let $p^2 = -a^2$

$$k_1 = \frac{-a^2}{b^2-a^2}$$

also

$$k_2 = \frac{-b^2}{-b^2+a^2}$$

$$\frac{p^2}{(p^2+a^2)(p^2+b^2)} 1 = \left(\frac{-a^2}{b^2-a^2}\right)\frac{1}{p^2+a^2} + \left(\frac{-b^2}{a^2-b^2}\right)\frac{1}{p^2+b^2} \Bigg] 1$$

$$= \left(\frac{a^2}{a^2-b^2}\right)\frac{1}{a^2}(1-\cos at) + \frac{b^2}{b^2-a^2}\frac{1}{b^2}(1-\cos bt) 1$$

$$= \frac{1}{a^2-b^2}(1-\cos at) + \frac{1}{b^2-a^2}(1-\cos bt) 1$$

$$= \frac{1}{\frac{L_1}{C_2(L_1L_2-M^2)} - \frac{L_2}{C_1(L_1L_2-M^2)}}\left(1-\cos\sqrt{\frac{L_1}{C_2(L_1L_2-M^2)}}\,t\right) +$$

$$\frac{1}{\frac{L_1C_1 - L_2C_2}{C_1C_2(L_1L_2-M^2)}} \quad ''$$

$$\times \frac{MQ_0}{C_1C_2(L_1L_2-M^2)}$$

$$e_{C_2} = \frac{C_1C_2(L_1L_2-M^2)}{L_1C_1-L_2C_2}\left(1-\cos\sqrt{}\,t\right) + \frac{C_1C_2(L_1L_2-M^2)}{L_2C_2-L_1C_1}(1-\cos bt).$$

$L_2 = 2.67\,h.$

$L_1 = .002\,h. \qquad M = .037.$

$L_1L_2 - M^2 = 2.67 \times .002 - .037^2$

$.00534 - .00137$

137

$(L_1L_2 - M^2)\ .00400$

$C_1 = 0.25 \times 10^{-6}$ farads. ✓

$C_2 = 50 \times 10^{-12}$ farads. est.

$C_1C_2 = 0.25 \times 10^{-6} \times 50 \times 10^{-12} = 12.5 \times 10^{-18}$

$L_1C_1 = .002 \times .25 \times 10^{-6} = .50 \times 10^{-9}$

$L_2C_2 = 2.67 \times 50 \times 10^{-12} = 133 \times 10^{-12}$

$= .133 \times 10^{-9}$

$$e_{c_2} = \frac{\cancel{C_1C_2(L_1L_2 - M^2)}}{L_1C_1 - L_2C_2}\left[\cos\sqrt{\frac{L_1}{C_2(L_1L_2-M^2)}}\,t - \cos\sqrt{\frac{L_2}{C_1(L_1L_2-M^2)}}\,t\right]\frac{MQ_0}{\cancel{C_1C_2(L_1L_2-M^2)}}$$

$$= \frac{MQ_0}{L_1C_1 - L_2C_2}\left[\cos at - \cos bt\right].$$

$$\frac{de_{c_2}}{dC_1} = \left(\frac{MQ_0}{L_1C_1 - L_2C_2}\right)\left[\cancel{(\sin at)a}^{\,0} + \sin bt\,\frac{d}{dC_1}\left(\sqrt{\frac{L_2}{C_1(L_1L_2-M^2)}}\,t\right)\right.$$

$$\sin bt\left[C_1^{-3/2}\left(-\tfrac{3}{2}\right)\sqrt{\frac{L_2}{L_1L_2-M^2}}\,t\right]$$

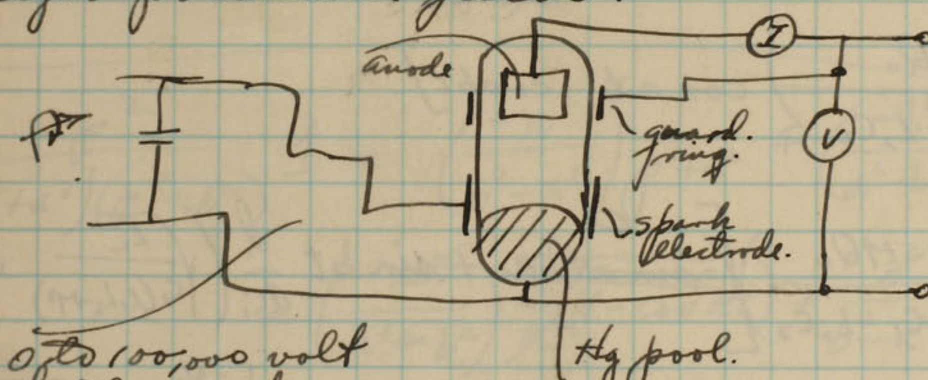
$$+\left[\cos at - \cos bt\right]\frac{-MQ_0}{(L_1C_1 - L_2C_2)^2}$$

April 5, 1934.
H.E. Edgerton

Germeshausen, Grier, and I went out to the Raytheon company this afternoon and talked to Bellenbaugh, Spencer and others. They gave us a three phase tube with grids for use as a thyratron.

Loaded up the stroboscope and camera for a trip out to the United Shoe Machinery Co at Beverly, Mass. where we are going to demonstrate the outfit to them.

Experiment to find mechanism of electron emission from mercury due to high potential fields.



April 9, 1934 Worked nearly all day yesterday on the U.S. Gillette pictures.

On Friday Apr. 6. (my 31st birthday) we took the h.s. camera out to the Beverly plant of the United Shoe Machinery Corp and took about 300 ft of pictures at 1200 frames per second on 35 mm of a leather sewing machine. These have been titled up and printed. Wilkins of General Radio went along on this trip.

Apr. 10. 1934. Harington and two others from the United Shoe Machinery company were here at tech yesterday afternoon and we showed them the reel of pictures which we took of their stitching machine.

April 11, 1934
~~Stroboscope~~

Tried to get some moving picture of the ~~breaking~~ shooting of an arrow last night. Taylor helped. A close up picture of the arrow should give greater accuracy of the measurements than last week.

One picture was too quick and the next was too ~~long~~ late to catch the arrow.

Pike of the Puzzel Box co was in and we helped him get his stroboscope together and running again.

April 23 1934. All ready for a trip to Atlantic City to present a paper to the Society for Motion Picture Engineers. Bennett is going along. We then go to Washington to attend the American Physical Society meeting on Thurs and Friday.

Wilkins of G.R. brought the camera over and I plan to take it. Also he brought over the small stroboscope using the neon tube see page 77 and a lamp holder for seven Hg lamps, 1 ft straight variety.

April ~~29~~ 30 1934. Had a great trip! returned last night. Stayed at 21 west 11 th with the Pognes on tues night. Arrived in Atlantic City about 10 am. and gave paper about 1:30. H. I Day of the E.R.P.I. was there and several others from that company. Made plans to stop in to see Day on Sat. am. on return from Washington. I did and found trouble with his stroboscope which was short one wire.

Program of Atlantic City meeting of
the Society of Motion Picture Engineers.

Notebook Number: T-4

Scanning and Separation Record

____unmounted photograph(s)

2 negative strip(s)

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

was/were scanned where originally located between page 98 and 99.

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

ter,

Joe Rydart is going to make some more tubes. We hope only 8.

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... negatives is going to make some more tests. We had
only 8.

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[illegible] is going to make some more tubes. We had only 8.

PROGRAM

OF THE

SPRING CONVENTION

OF

THE SOCIETY

OF

MOTION PICTURE ENGINEERS

SMPE

April 23rd to 26th, 1934

CHALFONTE-HADDON HALL ATLANTIC CITY, N. J.

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... is going to make some more cuts. We have only 8.

PROGRAM

MONDAY, APRIL 23RD

9:00 A. M. *Viking Room*: **Registration.**

10:00 A. M. General Session.

Society Business.

Report of the Progress Committee; J. G. Frayne, *Chairman*.
"Technical Committees—Their Organization and Policies"; L. A. Jones, *Engineering Vice-President.*

Report of the Committee on Standards and Nomenclature; M. C. Batsel, *Chairman.*

"History of Sound Pictures"; W. E. Theisen, *Honorary Curator*, Los Angeles Museum, Motion Picture Division, Los Angeles, Calif.

"Some Early Experiments in Photographic and Motion Picture Work"; F. E. Ives, Philadelphia, Pa.

"Oscilloscope"; H. F. Mallina, Bell Telephone Laboratories, New York, N. Y.

11:30 A. M. Projectionists Meeting.

Special meeting for Atlantic City projectionists, exhibitors, and managers; Addresses by Dr. Alfred N. Goldsmith, *President*, Mr. F. H. Richardson, and Mr. William Reed, of Atlantic City. Representatives of the local theatres and of the Projectionists' Local No. 310 will attend.

1:30 P. M. *Benjamin West Room*: **Informal Luncheon.**

Addresses by several prominent speakers, names to be announced later.

3:00 P. M. (A) Sound Session.

"Some Recent Improvements in Equipment and Technique in the Production of Motion Pictures"; E. A. Wolcott, RKO Studios, Hollywood, Calif.

"The Engineer's Contribution to the Development and Marketing of RCA Victor Photophone Sound Equipment"; J. Frank, Jr., RCA Victor Company, Camden, N. J.

"The Photographic Disc Recorder"; E. D. Cook, RCA Victor Company, Camden, N. J.

"A Demonstration of the Properties of Wave Filters"; C. E. Lane, Bell Telephone Laboratories, New York, N. Y.

7:30 P. M. *Rutland Ro*

Address by Mr. Sol
NRA, broadcast
Broadcasting Co
tertainment.

THU

9:30 A. M. (A) Labora

"Continuous Optical
York, N. Y.

"A Non-Slip Sound P
pany, Camden, N

"An Optical Reducti
L. T. Sachtleben,

Open Forum: "Sug
Picture Laborato
Applications of t

9:30 A. M. (B) General
"Properties of Piezoel
phone Laborator

"The Keller-Dorian P

"The English Dufayc
York, N. Y.

"A Year's Practical E
Camera"; H. T. D
New York, N. Y.,
pany, Rochester,

Apparatus Symposium

"A Small Develop
Debrie, Inc.,

"Camera for Sub
Pasadena, Ca

"Piezoelectric Mic
velopment Co

"Theatre Seats D
tics"; P. F. M
York, N. Y.

"Camera and Project
R. S. Hopkins, E
N. Y.

...gaard is going to make some more cells. We hop
only 8.

3:00 P. M. (B) **Amateur and 16-Mm. Session.**

"A Sixteen Millimeter Sound Camera"; G. L. Dimmick, C. N. Batsel, and L. T. Sachtleben, RCA Victor Company, Camden, N. J.

"Sixteen Millimeter Sound Motion Pictures in Color"; C. N. Batsel and L. T. Sachtleben, RCA Victor Company, Camden, N. J.

Report of the Committee on Non-Theatrical Equipment; R. F. Mitchell, *Chairman.*

"Problems of the Amateur Motion Picture Maker"; R. C. Holslag, Amateur Cinema League, New York, N. Y.

"Hand Synchronized 16-Mm. Sound Pictures"; H. Jones, Buffalo, N. Y.

"Recent Examples of 16-Mm. Sound Pictures on Double Sprocket Hole Film"; A. W. Carpenter, H. J. Hasbrouck, J. F. Nielsen, and E. R. Ross, United Research Corporation, Long Island City, N. Y.

TUESDAY, APRIL 24TH

9:30 A. M. **Projection Session.**

"Factors Covering the Design of Projection Lamps, and Their Application to Equipments"; F. E. Carlson, General Electric Company, Cleveland, Ohio.

"The Relationship of the High-Intensity A-C Arc to the Light on the Projection Screen"; D. B. Joy and E. R. Geib, National Carbon Company, Cleveland, Ohio.

"Operating Characteristics of the High-Intensity A-C Arc for Motion Picture Projection"; D. B. Joy and E. R. Geib, National Carbon Company, Cleveland, Ohio.

"A-C Adapters for Low-Intensity Reflecting Arc Lamps"; R. Miehling, New York, N. Y.

Report of the Projection Practice Committee; H. Rubin, *Chairman.*

"Effect of Aperture Lenses on the Illumination of Motion Picture Screens"; W. B. Rayton, Bausch & Lomb Optical Company, Rochester, N. Y.

1:30 P. M. **Exchange and Theatre Session.**

"Simple Theory of Three-Element Vacuum Tubes"; H. A. Pidgeon, Bell Telephone Laboratories, New York N. Y.

Report of the Sub-Committee on Exchange Practice; T. Faulkner, *Chairman.*

"Reel Problems in Exchange Practice"; T. Faulkner, S. M. Chemical Company, New York, N. Y.

"Technical Aspects of Theatre Operat
L. W. Conrow, Electrical Researc
York, N. Y.

"Cheapness Does Not Always Pay"; I
York, N. Y.

"The Motion Picture Theatre Audit
New York, N. Y.

Open Forum: "What is Wrong with t
Picture?" "How can the S. M. P
vice to the Industry?"

WEDNESDAY, APRIL 25

9:30 A. M. (A) **Sound Session.**

"Some Considerations in the Design
Equipment"; F. C. Willis and G.
search Products, Inc., New York,

"An Improved Sound System for
G. L. Dimmick and H. Belar, R
Camden, N. J.

"On the Realistic Reproduction of S
Reference to Sound Motion Pictu
F. Massa, RCA Victor Company,

Report of the Sound Committee; L. W

"Recent Optical Improvements in W
Film Recording Equipment"; W
phone Laboratories, New York, N

"Care and Operation of Theatre Sound
and P. T. Sheridan, Electrical Re
New York, N. Y.

9:30 A. M. (B) **Lighting Session.** ✓

"Studio Lighting"; S. W. Woodside
Company, Bloomfield, N. J.

"The Application of the Bi-Plane Fila
Spotlighting Service"; G. T. Mil
Company, Bloomfield, N. J.

"Developments in Spotlighting"; H.
Stagelighting Company, New Yor

"Theatre Lighting, Using Thyratron
General Electric Company, Clevel

"Visual Accompaniment for Record
Audio Productions, Inc., New Yor

"Stroboscopic Light High-Speed Photo
ton and H. Germeshausen, Mass
Technology, Cambridge, Mass.

Joe Rydant is going to make some more tubes. We have only 8.

"Technical Aspects of Theatre Operation"; R. M. Wilcox and L. W. Conrow, Electrical Research Products, Inc., New York, N. Y.

"Cheapness Does Not Always Pay"; F. H. Richardson, New York, N. Y.

"The Motion Picture Theatre Auditorium"; B. Schlanger, New York, N. Y.

Open Forum: "What is Wrong with the Shape of the Motion Picture?" "How can the S. M. P. E. Be of Better Service to the Industry?"

WEDNESDAY, APRIL 25TH

9:30 A. M. (A) **Sound Session.**

"Some Considerations in the Design of Sound Reproducing Equipment"; F. C. Willis and G. Friedl, Electrical Research Products, Inc., New York, N. Y.

"An Improved Sound System for Noiseless Recording"; G. L. Dimmick and H. Belar, RCA Victor Company, Camden, N. J.

"On the Realistic Reproduction of Sound, with Particular Reference to Sound Motion Pictures"; H. F. Olson and F. Massa, RCA Victor Company, Camden, N. J.

Report of the Sound Committee; L. W. Davee, *Chairman.*

"Recent Optical Improvements in Western Electric Sound Film Recording Equipment"; W. Herriott, Bell Telephone Laboratories, New York, N. Y.

"Care and Operation of Theatre Sound Systems"; J. S. Ward and P. T. Sheridan, Electrical Research Products, Inc., New York, N. Y.

9:30 A. M. (B) **Lighting Session.**

"Studio Lighting"; S. W. Woodside, Westinghouse Lamp Company, Bloomfield, N. J.

"The Application of the Bi-Plane Filament Light Source to Spotlighting Service"; G. T. Mili, Westinghouse Lamp Company, Bloomfield, N. J.

"Developments in Spotlighting"; H. Kliegl, Kliegl Bros. Stagelighting Company, New York, N. Y.

"Theatre Lighting, Using Thyratrons"; C. F. Bateholtz, General Electric Company, Cleveland, Ohio.

"Visual Accompaniment for Recorded Music"; G. Lane, Audio Productions, Inc., New York, N. Y.

"Stroboscopic Light High-Speed Photography"; H. E. Edgerton and H. Germeshausen, Massachusetts Institute of Technology, Cambridge, Mass.

Joe Dyzarr is going to make ... only 8.

7:30 P. M. *Rutland Room*: **Semi-Annual Banquet.**

Address by Mr. Sol A. Rosenblatt, Division Administrator, NRA, broadcast over the red network of the National Broadcasting Company. *Dancing, Motion Pictures, Entertainment.*

THURSDAY, APRIL 26TH

9:30 A. M. (A) **Laboratory Session.**

"Continuous Optical Reduction Printing"; A. F. Victor, New York, N. Y.

"A Non-Slip Sound Printer"; C. N. Batsel, RCA Victor Company, Camden, N. J.

"An Optical Reduction Sound Printer"; C. N. Batsel and L. T. Sachtleben, RCA Victor Company, Camden, N. J.

Open Forum: "Suggestions for Improvements in Motion Picture Laboratory Practice." "Possible Motion Picture Applications of the Principle of Auditory Perspective."

9:30 A. M. (B) **General Session.**

"Properties of Piezoelectric Crystals"; F. R. Lack, Bell Telephone Laboratories, New York, N. Y.

"The Keller-Dorian Process"; P. D. Brewster, Newark, N. J.

"The English Dufaycolor Film Process"; W. H. Carson, New York, N. Y.

"A Year's Practical Experience with a High-Speed Timing Camera"; H. T. Day, Electrical Research Products, Inc., New York, N. Y., and F. Tuttle, Eastman Kodak Company, Rochester, N. Y.

Apparatus Symposium:

"A Small Developing Machine"; H. R. Kossman, Andre Debrie, Inc., New York, N. Y.

"Camera for Submarine Photography"; L. F. Douglas, Pasadena, Calif.

"Piezoelectric Microphones"; A. L. Williams, Brush Development Company, New York, N. Y.

"Theatre Seats Designed for Correct Sight and Acoustics"; P. F. Masucci, International Seat Corp., New York, N. Y.

"Camera and Projector for Newspaper Library Work"; R. S. Hopkins, Eastman Kodak Company, Rochester, N. Y.

Joe Rydart is going to make some more tubes. We have only 8.

1:30 P. M. Photographic Session.

"Some Properties of New Agfa 35-Mm. Film"; P. Arnold, Agfa Ansco Corporation, Binghamton, N. Y.

"The Failure of the Reciprocity Law in Photographic Exposure"; J. H. Webb, Eastman Kodak Company, Rochester, N. Y.

"The Microdensitometer as a Laboratory Measuring Tool"; W. R. Goehner, Bell Telephone Laboratories, New York, N. Y.

"A Sweep Oscillator Method of Securing Wide Band Frequency Response Spectra on Short Lengths of Motion Picture Film"; J. Crabtree, Bell Telephone Laboratories, New York, N. Y.

"Problems Involved in Talking Pictures from the Air"; Fairchild Camera Corporation, New York, N. Y.

ADJOURNMENT OF THE CONVENTION

Note: The Society of Motion Picture Engineers will not be responsible for statements made by authors.

Convention Committee,
W. C. Kunzmann, *Chairman.*

Papers Committee,
J. O. Baker, *Chairman.*

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Joe Rydarit is going to make some more tubes. We have only 8.

May 8, 1934.

Experimented with new metalic lamp holder built by Several Radios. The two outside tubes seemed to flicker some indicating that the metal sides affect starting. Sample films put in book and may stay. Wilkins came over and we discussed a new lamp house with several feature such as.

1. Non metalic holder
2. One inch clearance on the spark leads
3. Separate + and - leads to the condensers. (The present model has a common anode lead.
4. Small capacity for the spark secondary circuit.

Etc.

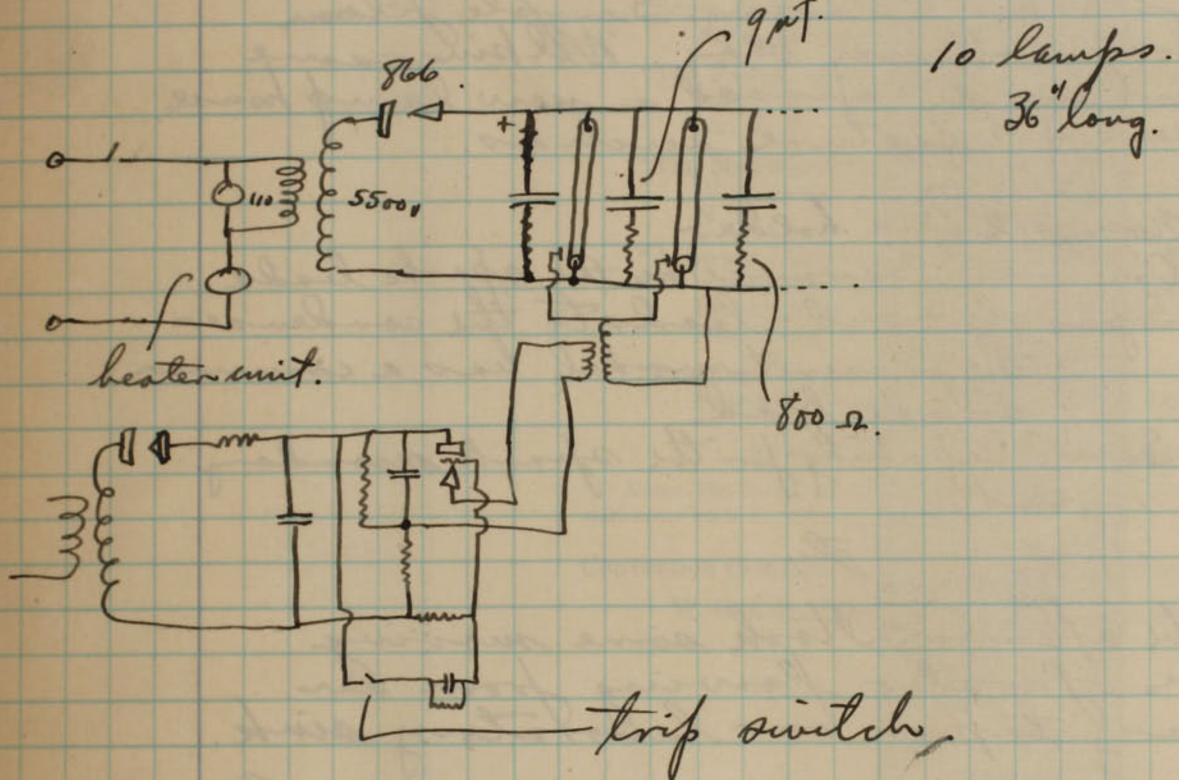
In the afternoon I took some moving pictures of water flowing from an ordinary tap in our laboratory sink.

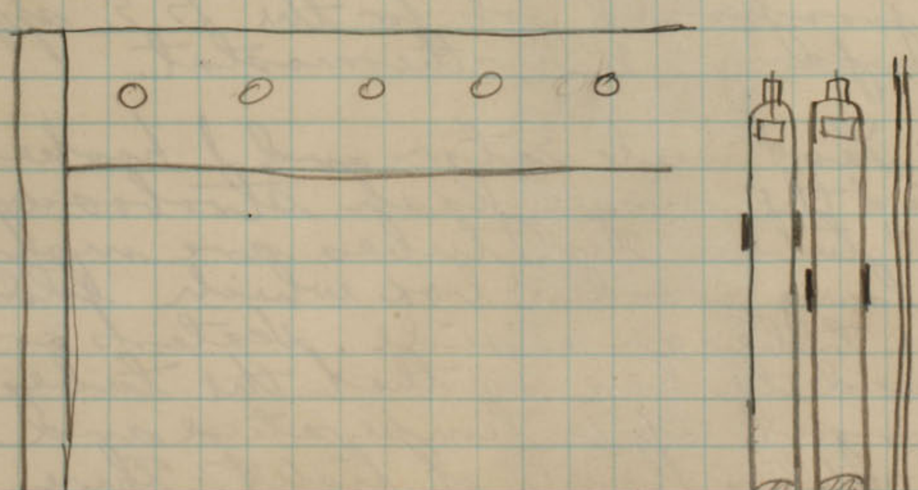
Mr. Guild was over and wants to take our camera down to Mr. Austin's place in Eastham(?) on the cape to photograph birds in flight.

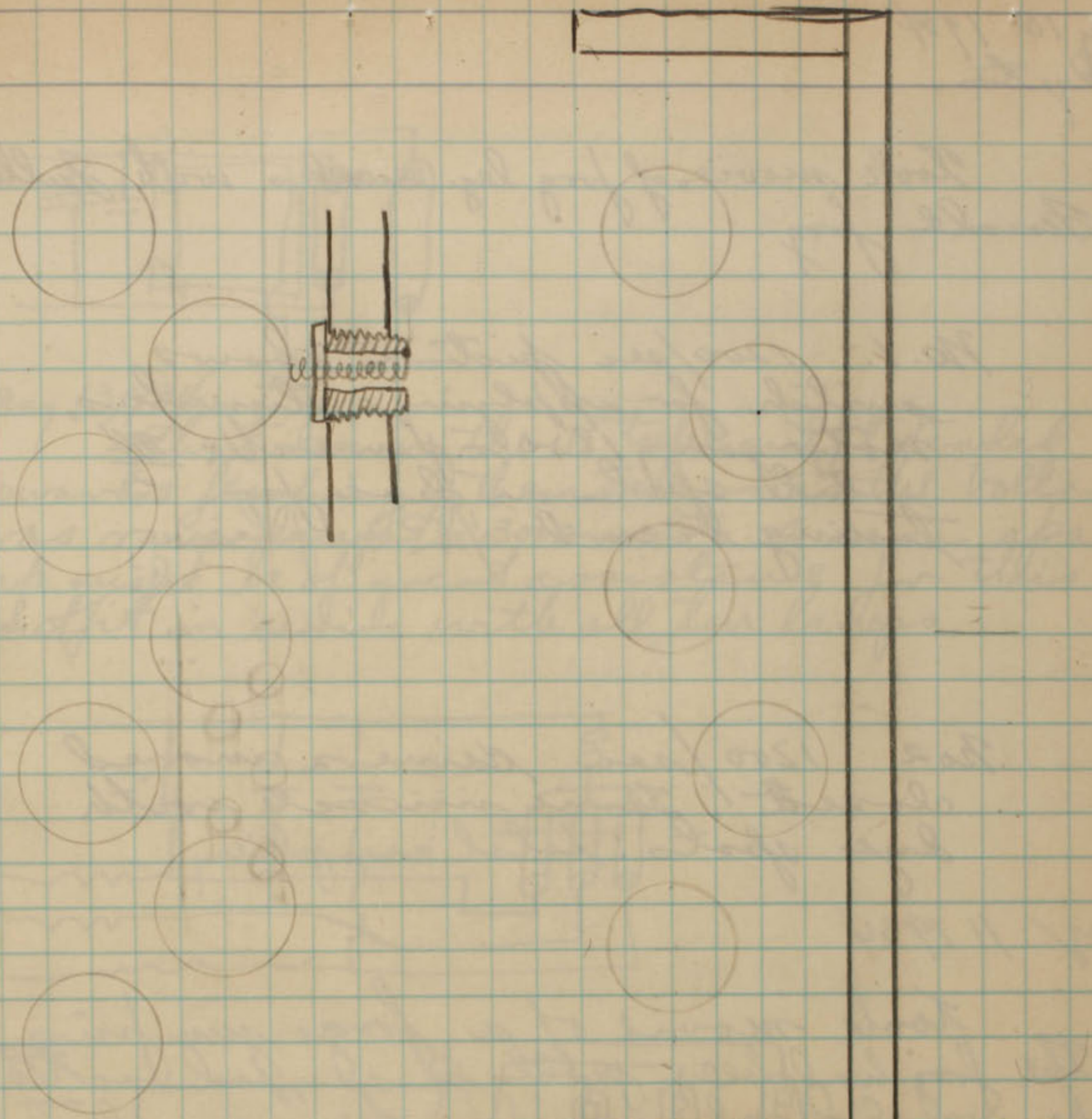
Frank Tucker was over and discussed a proposed job for the G.E. appliance company. Water thermostat.

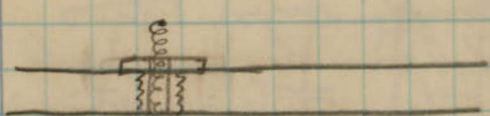
Last week Eaton and I hooked up and tried the single flash stroboscope using 36" tubes. Ten tubes are mounted in a long wooden box which folds in the center, five tubes on a side. Heaters are located inside the box so that the tubes may be brought up to temperature and so produce a brighter flash of light. There was some tendency for the outfit to flash by its self when the voltage reached about 3 000. Joe Rydant is going to make some more tubes. We have only 8.

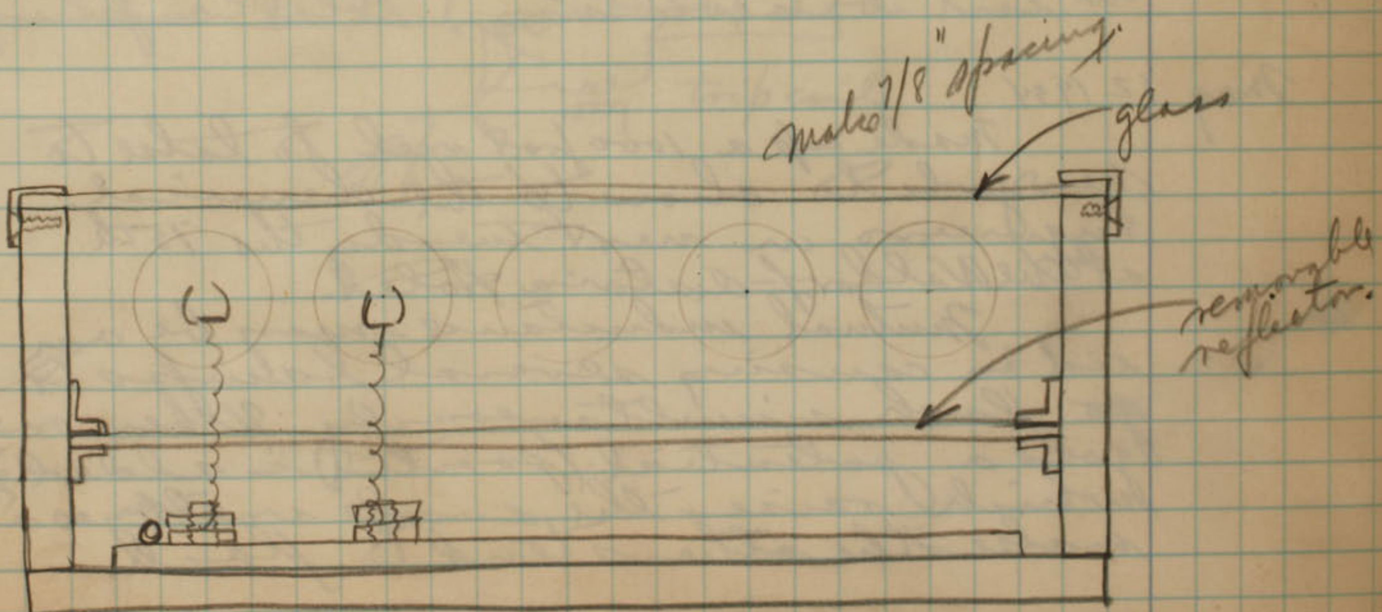
The circuit for this flashing outfit is given below except for minor details.










make 7/8" spacing
glass
removable reflector.

May 10 1934
H.E. Edgerton.

Took movie of frog leg muscles with Fuller Fernald frog.

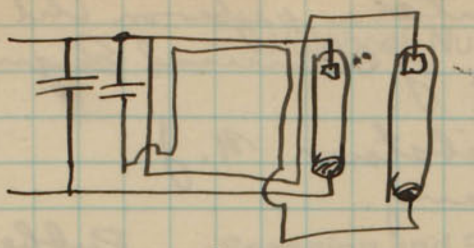
No. 1. 1200/sec picture shows switch for applying stimulus, motor going 1800 r.p.m with $\frac{34}{2}$ white spots on disc for timing record ½ coupling.

No 2 1200/sec. camera moved closer. Same muscle with dye spots. total coupling.

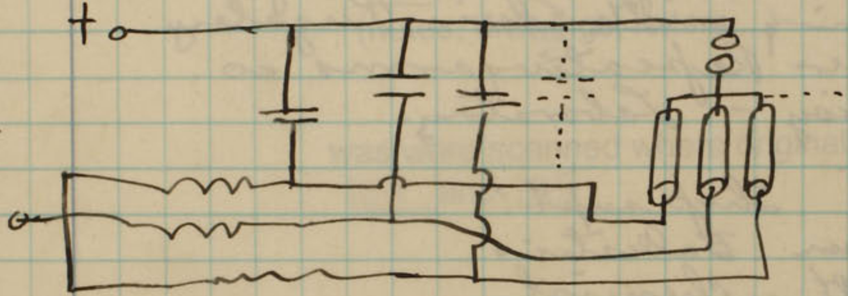
May 11 1934

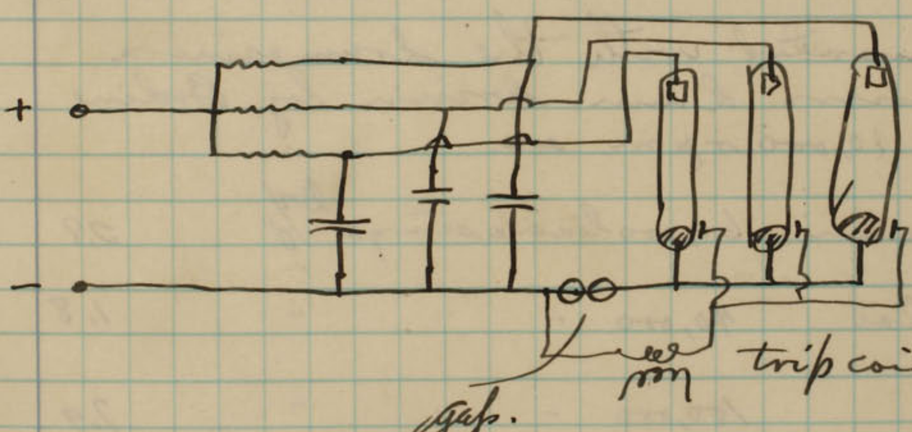
took movie of a frog jumping. The frog had been partly paralyzed so that he would only jump when an electrical current was sent through him. two electrodes were put on his back at the base of his spine. the interrupter on the coil was working. total coupling.

May 12 1934
Made up a 1000 foot reel to take to New York to show to the chemical Engineers on next tuesday the 15th at the Waldorf-Astoria Hotel.
Mutual inductance may be an aid in causing several lamps to ~~go~~ flash simultaneously. When one goes a potential (positive) is added which raises the anode voltages and makes the others tend to flash.



May 13 1934.
The tubes in the 10 tube outfit tended towards flashing by themselves as the voltage was raised up to 3000 volts. A series spark gap might be of great assistance for this outfit in series with all ten lamps.





H. E. Edgerton
May, 17. 1934.

On May 15 I presented a paper on the stroboscope to the Society of Chemical Engineers at the Waldorf astoria.

S. L. Sandforth Gibstown N. J.
Dupont company.

Harland ~~Turnbull~~ · Goodrich ~~Tire~~ Rubber Co.

Geo F. Rugar. N. Y. Friend of Slater.

Stayed with Mary Ellen and Welch (Pogue) at 21 west 11 that night and left for New Haven the next morning on the 6 am train.

Spent morning with Edwin Pugsley at the Winchester Repeating arms co.

Mr. Foisy - Laboratory.
Smith.
Book Shop supt?
Robinson Ballestics
McNutt chemist.

Experimented with the drum camera 1 ft duraluminum drum driven by Bodine motor 1 hp 10,000 rpm a.c.

			Stren/Densit
Duraluminum	60,000 tensile strength lbs/□"	2.8	21,400.
Dow metal	40,000 " " "	1.8	22,200
Steel	100,000 " " "	7.9.	12,750.

Properties of Duraluminum Dow metal and Steel.

May 18. 1934. Gems and Grier to Lowell at masonic dinner.

I worked with Fuller during the afternoon and evening taking movies of the reaction of frog muscles. Some difficulties were experienced with the camera in obtaining satisfactory exposures on positive film. Heretofore no difficulty has been experienced this way.

Notebook Number: T-4

Scanning and Separation Record

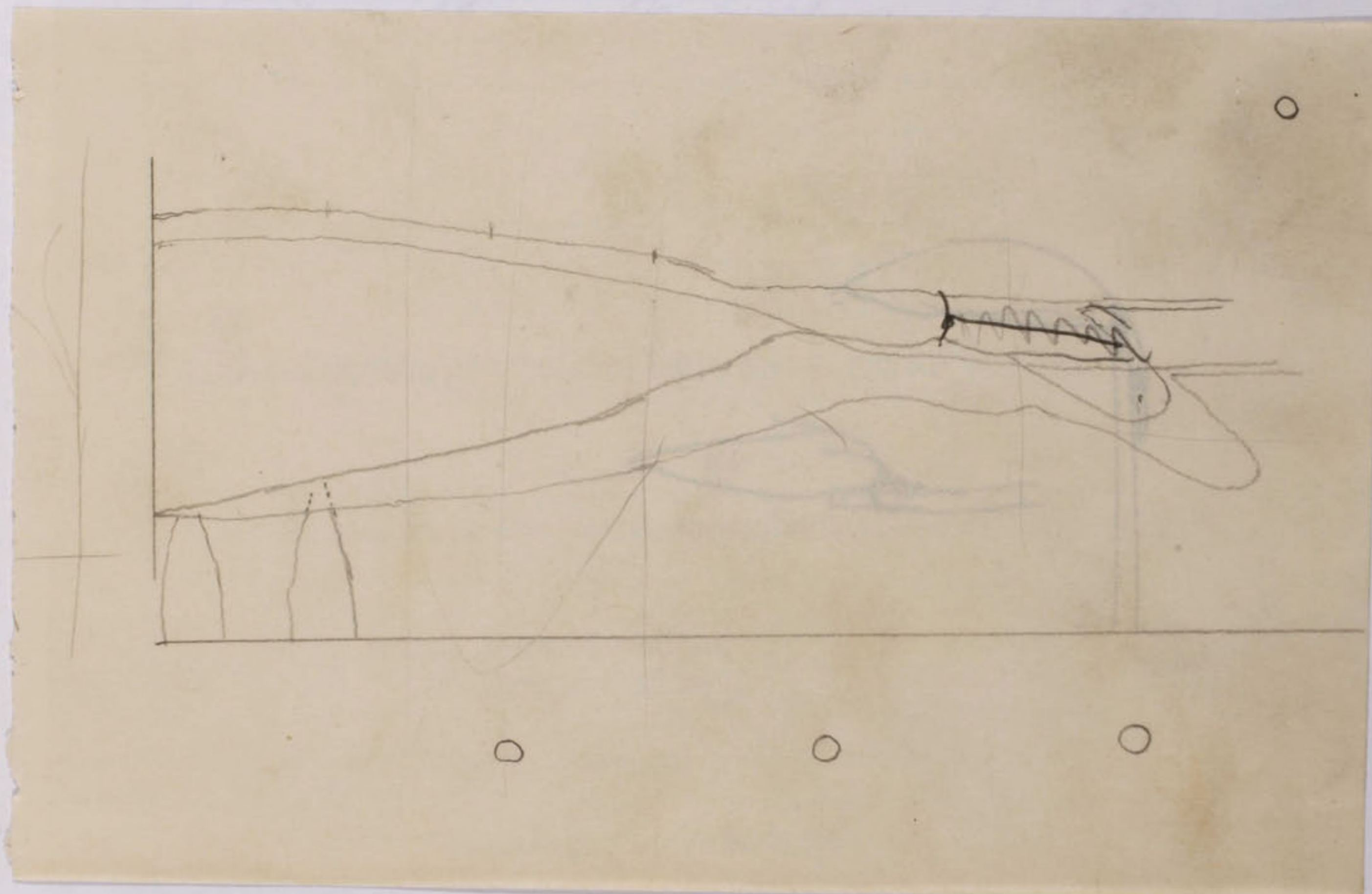
____unmounted photograph(s)

____negative strip(s)

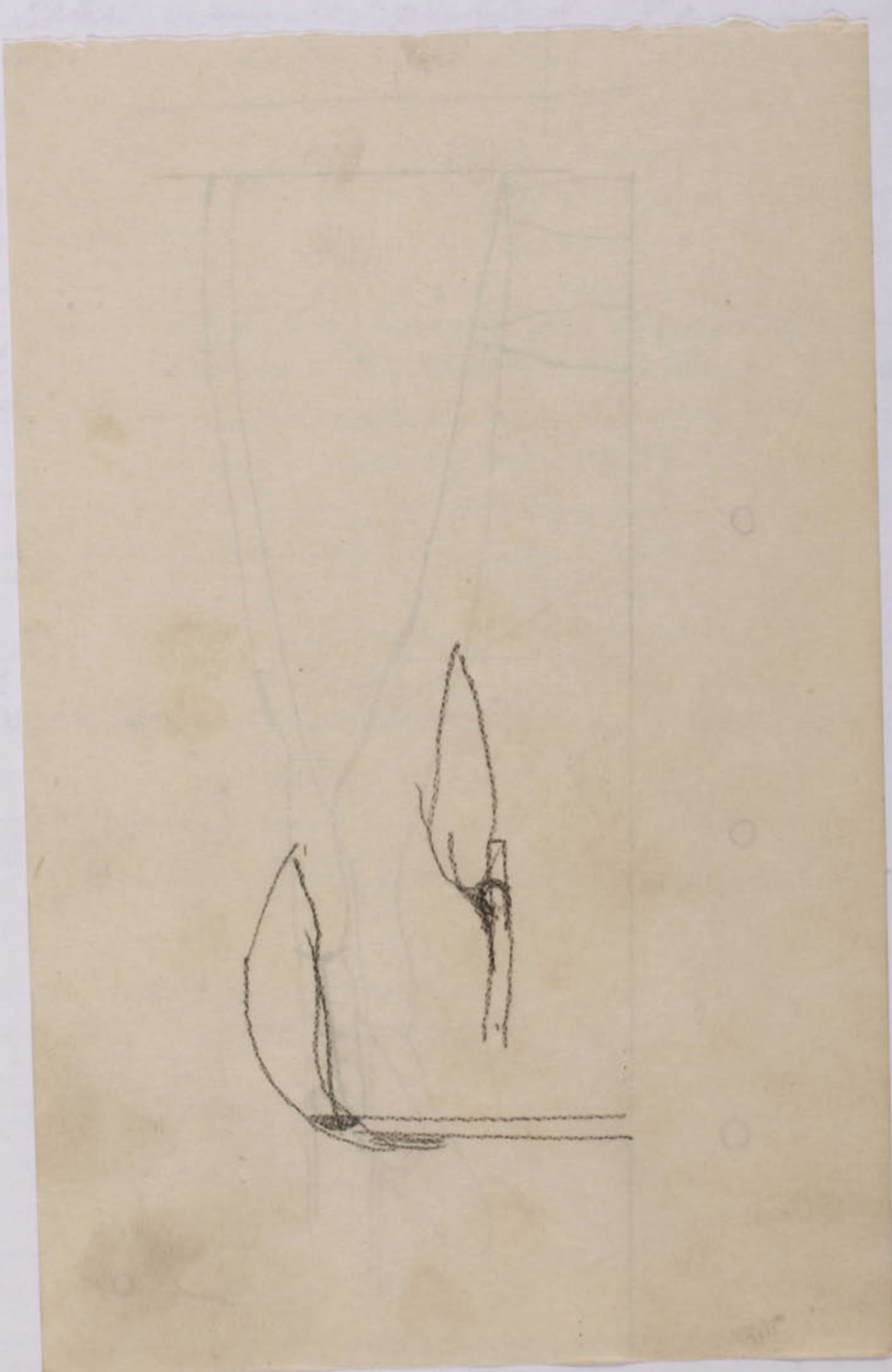
1 unmounted page(s)
(notes, drawings, letters ...)

was/were scanned where originally located between page 104 and 105.

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



10
cm
=7,5
m.
=
cm.

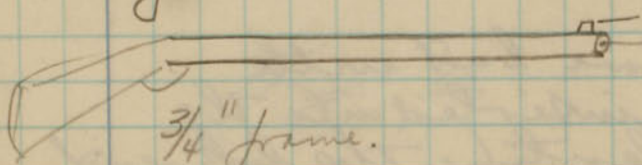


the spark missed some because of insufficient power into the trip circuit.

The muscle pulled at an angle which through the lower part over. A scheme needs to be found for correcting this. Another difficulty in analyzing the results is to be able to locate a specific point on the muscle.

May 19. Analyzed the films and discussed them with Fuller and with Bunker. Plan to work again next monday.

May 20



Winchester.

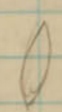
3/4" frame.

1" on film made four feet on screen 4x12 = 48

50 to 1 enlargement.

.005" = .25 of an inch

$$\frac{1}{f'} + \frac{1}{f_2} = \frac{1}{F}$$



$f_1 = f_2$ $\frac{2}{f} = \frac{1}{5}$ $f = 10$ cm

$f_1 = 2f_2$ $\frac{1}{f_1} + \frac{1}{2f_1} = \frac{1}{5}$

$\frac{2f_1 + f_1}{2f_1^2} = \frac{1}{5}$ $f_1 = \frac{3 \cdot 5}{2} = 7.5$

$f_2 = 15$ cm.

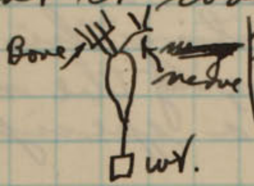
$f_1 = 3f_2$ $\frac{1}{f_1} + \frac{1}{3f_1} = \frac{1}{5}$ $f_1 = \frac{4 \cdot 5}{3} =$

$f_2 = 20$ cm.

May 16 1934
H. E. Edgerton.

Muscle contraction experiments.

Film No. 1. Muscle held at a slight angle so that it would pull up without twisting.



the stimulus was given by an electrical surge on the nerve going to the muscle

Film No 2. Same as above but with muscle turned 90 degrees to give a view of the other plane.

No 3. Repeat of above but with small glass needles inserted into the muscle in order to identify the different portions during the contraction.

No. 4. Repeat but with muscle in the other plane.

Bosch Spark coil data.

Measured by N. C. Thomas and H. C. Swan

$L_2 = 2.59\,h.$

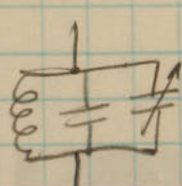
$R_2 = 3060$ ohms.

$C = 90$ mmf distributed capacity.

$M = 37.8$ mh. $\qquad L_1 = 2$ mh.

$R = 0.6$

$$\frac{M}{(L_1 L_2)^{\frac{1}{2}}} = .52.$$

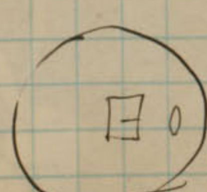


at resonance $j\omega L = \frac{1}{j\omega C} \qquad c = \frac{-1}{\omega^2 L} = \frac{1}{4\pi^2 f^2 L}$

from this $C = K' \frac{1}{f^2}$

$$\begin{array}{r} 6.28 \\ 2.2 \\ \hline 14. \end{array}$$

$$f = \frac{1}{2\pi\sqrt{.002 \times .25 \times 10^{-6}}} = \frac{1}{2\pi\sqrt{5. \times 10^{-10}}} = \frac{1}{2\pi\ 2.2 \times 10^{-5}} = \frac{10^5}{14.} = 10^4 = 10{,}000.$$



May 26, 1934

Took movies of small cavitation machine in the ~~engineering lab~~ M. E. Lab.

No. 1. exposure weak
2 " good. drops on glass
← 3. ok. small cavitation
4. " larger
5 " still larger
6. " more.

all above 3000 per second shadow. spark. 5 amp 1000 v

Germs took about 4 spark photos at f. 8. of ~~each~~ each of the above. Also ord. movies.

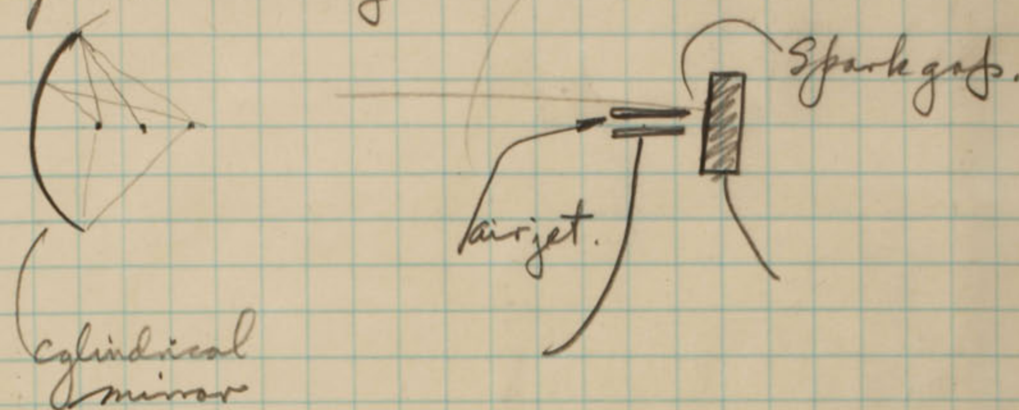
Went home about 3 p.m. to help Esther get ready to go west in car.

May 27 1934

I left yesterday 5.30 with Esther, and our children Mary Louise Byrd and William E. 10 months, for the west. We stopped for the night at Chester, Mass. This morning I went as far as Pittsfield where I took the train for Boston and they went west to Syracuse for the first day.

Returned to Tech and Eaton helped in the afternoon to copy some of the shot no. 3. for projection. Also took spark photos of smoke going through the blades of a fan.

Sparke apparatus for high frequency or high intensity!



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THE STROBOSCOPE AND HIGH-SPEED MOTION-PICTURE CAMERA AS RESEARCH INSTRUMENTS

By HAROLD E. EDGERTON * and KENNETH J. GERMESHAUSEN †

I. Introduction

Time is an important element in engineering processes and projects as well as in the normal routine happenings of the day. Production processes, new developments, and experiments of all kinds are scheduled, judged, and recorded as functions of time in units of years, months, weeks, days, hours, minutes, or seconds. For instance, the construction of a large building may require a year, and during this time charts showing the daily progress of the work are carefully recorded and studied by the constructors to guide them in finishing the work within the scheduled time interval. As another example, the motions of the hands of a girl assembling the elements of a radio tube are carefully studied in order to reduce lost motion and the time required for the construction of the tube. Since the hands move so quickly that some of the actions are lost to the eye of the observer, it has been common practice to use slow-motion pictures for the purpose of motion study. Such pictures taken, say, at 64 frames per second and projected at 16 per second, show the action slowed down by a factor of four, and make it possible to see motions normally lost to the eye. Furthermore, a study of the individual pictures themselves, frame by frame, often brings out obscure but important details. Similar motion studies of fast machinery are difficult because equipment is not commonly available for recording the information in a similar fashion.

The stroboscope and the stroboscopic-light, high-speed motion-picture camera are instruments of use especially in studying rapidly-moving objects, and the purpose of this paper is to discuss the ability and limitations of each in their application to engineering problems. The mercury-arc stroboscope lamps used in the particular type of

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stroboscopic apparatus described, were developed at the Massachusetts Institute of Technology in the Electrical Engineering Department, and successfully applied to the measurement of the oscillations of synchronous machines during transient conditions. Since then they have been applied to many other problems, a few of which will be described in this paper.

II. The Stroboscope

The stroboscope is applicable to the study of problems wherein the motions are periodic and of high enough frequency to utilize the

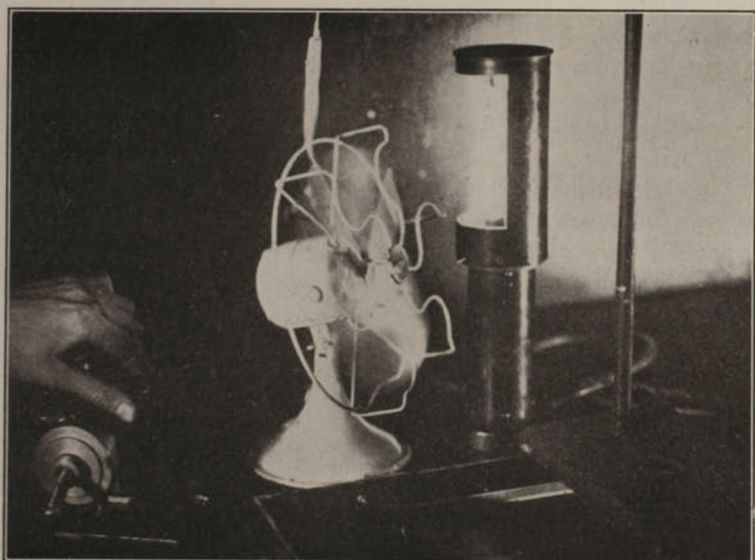

Fig. 1. A photograph showing a mercury-arc stroboscope illuminating an electric fan. The blades of the fan are visible in the photograph, although the continuous light shows a blur between the blades. A small piece of cloth saturated with titanium tetrachloride is used to produce smoke in order to investigate the flow of air through the fan blades.

persistence of vision. Since it is easy to use, it should be employed wherever possible in preference to photographic methods.

Stroboscopic effects have been observed for at least a century. The first experiments involved mechanical interruption of a beam of light, either before striking a rotating object or after being reflected

towards the eye. Studies of the conductio
to the development of more efficient types
light itself was not continuous but intermit
a neon-filled tube. The stroboscope des
mercury-arc lamp which has many usefu
with the neon tube, and in addition has a
for taking photographs.

The stroboscope depends upon the per
The periodic flashes of light produced by t
to be at a frequency of approximately tha
vation. Consider, for example, a wheel
revolutions per minute. Should the strob
flashes a minute, the wheel would appear
a flashing frequency of 3590 per minute
rotate forward at a speed which is the di
and the flashing speed, which in this case
which may be easily counted. Likewise,
the light be greater than the rotation speed
to rotate backwards at a speed which aga
irregularities in the speed of the wheel are
directly observable instead of being sup
speed of rotation.

Other motions than those of rotation a
oscope. In this classification are springs,
the flow of air through fan blades and c
crank shafts, and innumerable other movi
are that the motion shall be both (1) peri
high frequency to use the persistence of
960 per minute are difficult to observe
the eye fails to hold over the images and
A bright stroboscopic light source in a ve
sible to see even down to as low as 1
although the result may be far from sa
motion pictures are useful for cases invo
will be taken up later.

A great many times in engineering w
read the speed of an inaccessible part
which would be very appreciably slowed d
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scope

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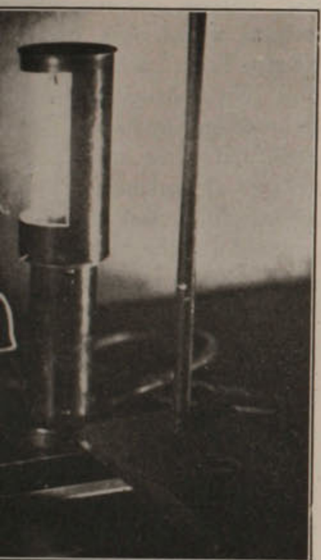

y-arc stroboscope illuminating an
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luce smoke in order to investigate

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graphic methods.
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al interruption of a beam of
bject or after being reflected

towards the eye. Studies of the conduction of electricity in gases led to the development of more efficient types of stroboscopes wherein the light itself was not continuous but intermittent. Many of these utilize a neon-filled tube. The stroboscope described in this paper uses a mercury-arc lamp which has many useful characteristics in common with the neon tube, and in addition has a quality of light more useful for taking photographs.

The stroboscope depends upon the persistence of vision of the eye. The periodic flashes of light produced by the stroboscope are arranged to be at a frequency of approximately that of the object under observation. Consider, for example, a wheel rotating at a speed of 3600 revolutions per minute. Should the stroboscope be adjusted to 3600 flashes a minute, the wheel would appear absolutely stationary. With a flashing frequency of 3590 per minute the wheel would appear to rotate forward at a speed which is the difference of the actual speed and the flashing speed, which in this case is 10 per minute—a speed which may be easily counted. Likewise, should the flashing speed of the light be greater than the rotation speed, then the wheel will appear to rotate backwards at a speed which again is the difference. Small irregularities in the speed of the wheel are very evident, since they are directly observable instead of being superimposed upon the actual speed of rotation.

Other motions than those of rotation are observable with the stroboscope. In this classification are springs, wires, braces, beams, liquids, the flow of air through fan blades and compressors, the vibration of crank shafts, and innumerable other moving parts. The requirements are that the motion shall be both (1) periodic, and (2) of sufficiently high frequency to use the persistence of vision. Speeds below about 960 per minute are difficult to observe with a stroboscope, because the eye fails to hold over the images and is bothered by the flicker. A bright stroboscopic light source in a very dark room makes it possible to see even down to as low as 100 revolutions per minute, although the result may be far from satisfactory. The high-speed motion pictures are useful for cases involving these low speeds, and will be taken up later.

A great many times in engineering work it becomes important to read the speed of an inaccessible part or a light delicate member which would be very appreciably slowed down by a tachometer. The stroboscope is an ideal instrument for reading speed in either of these

110

cases and many others, the only requirement being that the object can be seen. All that is necessary is to adjust the frequency of the stroboscopic light until the object appears stationary, since when this is true, the speeds of the two are identical. A determination of the speed of

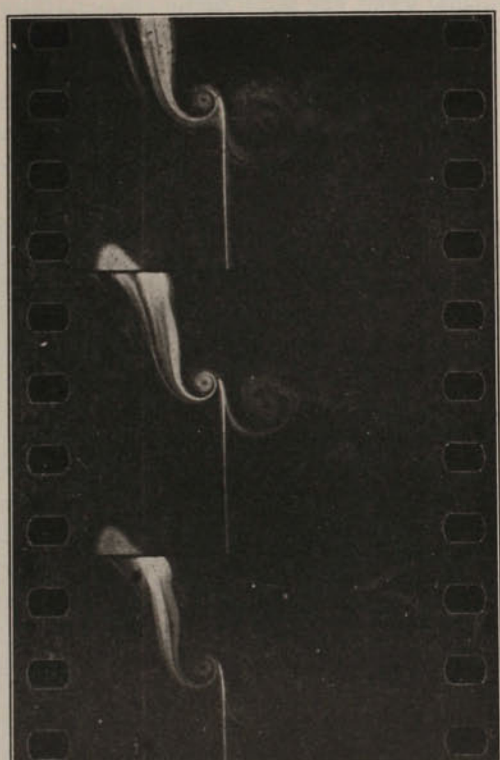


FIG. 2. Three enlarged frames from a 35-mm. motion picture showing a close-up view of the smoke (see Fig. 1) as it forms vortices on the ends of the blades. Taken with a standard 35-mm. camera, f3.5 lens, supersensitive panchromatic film.

the commutator immediately results in a determination of the speed of the object. One word of caution is necessary. The speed of the object may be a multiple of the speed of the commutator, since the object may rotate two times, three times, etc., between flashes and yet appear the same to the eye. It is impossible to get a fundamental

stationary pattern with flashing speeds gr
Therefore, if the speed of the stroboscope
highest speed which will give a stationary
which corresponds to the speed of the ob
mate speed is known; for instance, a spi
approximately 10,000 revolutions per min

A symmetrical radial pattern such as
number of evenly spaced spokes, may
results, since the spokes may be sufficient
to the eye because of their similarity. Co
avoided by painting or marking with chalk
a mark on the rim. Oftentimes these symm
relationships, since the number of identica
k, the speed of rotation, R, and the frequ
by a simple equation for the case givin
pattern.

Rk = Fn where R = speed in r.p.
F = flashes per m
k = number of e
n = any integer s

A more detailed explanation of this equ
given in one of the references.[2]

A few of the outstanding examples
are listed below:

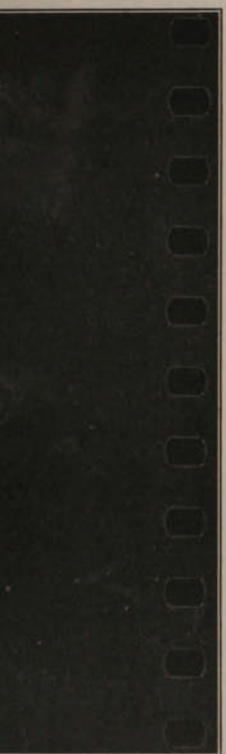
(1) *The study of vibrations.* By m
possible to study in detail the nature of
frequency, to determine the time-phase r
force, and to measure the amplitude.

(2) *Tachometer.* As has been descri
uses of the stroboscope is to measure sp

(3) *Meter calibration.* A standard
to time the interval between the flashes
light shining upon the meter to be cal
immediately adjust the setting until the
at which time the two meters are runnin

(4) *Watch adjustment.* A constant
a stroboscope lamp for quickly adjustin

rement being that the object can
just the frequency of the strobo-
ationary, since when this is true,
A determination of the speed of



frames from a 35-mm.
close-up view of the
ms vortices on the ends
th a standard 35-mm.
itive panchromatic film.

a determination of the speed of
necessary. The speed of the
l of the commutator, since the
es, etc., between flashes and yet
npossible to get a fundamental

stationary pattern with flashing speeds greater than the actual speed. Therefore, if the speed of the stroboscope is continuously raised, the highest speed which will give a stationary fundamental pattern is that which corresponds to the speed of the object. Usually the approximate speed is known; for instance, a spindle in a textile plant goes approximately 10,000 revolutions per minute.

A symmetrical radial pattern such as is given by a wheel with a number of evenly spaced spokes, may sometimes give erroneous results, since the spokes may be sufficiently identical to be confusing to the eye because of their similarity. Confusion of this sort is easily avoided by painting or marking with chalk one of the spokes or making a mark on the rim. Oftentimes these symmetrical patterns give useful relationships, since the number of identical elements around the circle, k, the speed of rotation, R, and the frequency of flash, F, are related by a simple equation for the case giving an apparently stationary pattern.

$$Rk = Fn \text{ where } R = \text{speed in r.p.m.}$$
$$F = \text{flashes per minute.}$$
$$k = \text{number of elements.}$$
$$n = \text{any integer such as 1, 2, 3, 4, etc.}$$

A more detailed explanation of this equation and its application is given in one of the references.[2]

A few of the outstanding examples of uses of stroboscopic light are listed below:

(1) *The study of vibrations.* By means of the stroboscope it is possible to study in detail the nature of vibrations, to measure their frequency, to determine the time-phase relationship to the disturbing force, and to measure the amplitude.

(2) *Tachometer.* As has been described, one of the most obvious uses of the stroboscope is to measure speeds.

(3) *Meter calibration.* A standard watthour meter[3] is employed to time the interval between the flashes of light. The stroboscopic light shining upon the meter to be calibrated enables the tester to immediately adjust the setting until the dial appears to be stationary, at which time the two meters are running at identical speeds.

(4) *Watch adjustment.* A constant frequency may be used to trip a stroboscope lamp for quickly adjusting the regulation of a watch.

The development of a scheme of this type[4] was recently announced.

(5) *Observation and adjustment of periodic production operations.* In this classification are envelope folders, bread slicers, packaging machinery, paper cutters—where registration of the cutter with a design is important—and multicolor printing on paper and cloth.

(6) *A high-speed clock hand.* The General Radio Company uses a stroboscopic lamp so arranged as to be flashed by the time signals from Arlington. A hand on the clock, rotating ten times per second, permits comparison of times to be made to an accuracy of 1/5000th of a second.

III. High-Speed Motion Pictures

There are many events in this life that happen too quickly to be seen by the unaided eye. Either too much information is presented in too short a time for the brain to record, or the motion of a particular object is too rapid for the eye to follow.

It has been seen that the stroboscope is useful in slowing down repetitive or periodic events, but for those events that do not repeat at regular intervals with a frequency of greater than about 16 a second, the high speed camera is the only tool at present available to enable the eye to see what is happening.

Motion pictures of this type are taken with the camera driven at a rate greater than normal, and are then projected at the usual rate. The projected picture shows the motion of the subject slowed down by that ratio by which the camera was speeded up.

Further than allowing one to see the event at a reduced speed, high-speed photography enables one to make accurate measurements of velocities, accelerations, and displacements. If motion pictures of an event are taken and the time between successive pictures is accurately known, displacements between successive pictures can be measured, and, since the time is known, it is possible to compute the acceleration and velocity.

A short exposure time is important for measurements of the type described above, since a short exposure reduces the blur of the image of the moving object on the film. Stroboscopic photography with its exposures of less than one one-hundred-thousandth of a second is particularly useful in measurements of the motions of high-speed objects. For instance, the golf ball velocity study which is given later as an example would be very difficult if the exposures were even as

long as one ten-thousandth of a second,
about 1/4 of an inch (about 1/6 of the d
the exposure time.

It seems to be impractical to speed u
motion-picture mechanism to speeds mu
normal because of inherent mechanical di
it may be said that all types of high-speec
than about 160 pictures per second must
film instead of intermittently-moving filr
continuously-moving-film cameras:

(1) Those employing a moving optic
stationary with respect to the film during

(2) Those employing an intermittent
whose flashes are of sufficiently brief du
on the moving film.

Each of these two types of camera
advantages which need to be carefully cc
particular problem at hand. The first typ
adapted to the study of subjects which p
mon examples of which are the burnir
explosives, the motions of an electric arc,
bulb, and the behavior of the cathode s
stroboscopic-light type of camera is of v
of problems such as these.

The principal advantage of the strob
over the moving-optical-system type is th
effectively stops the motion of rapidly-r
sure. The stroboscopic light gives an e
lionths of a second, which is considerabl
the moving-optical-system method, especi
as possible is usually desired in the m
order to get sufficient density on the f
employing stroboscopic light the film is r
stant speed, and each time the film has
by one picture, the subject is illuminated
light. The time at which the flash occu
tator rigidly attached to the film-driving
of the flash is so short that no apprec
occurs. The particular type of stroboscc

type[4] was recently announced.
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city study which is given later
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long as one ten-thousandth of a second, since the ball would move about 1/4 of an inch (about 1/6 of the diameter of the ball) during the exposure time.

It seems to be impractical to speed up the ordinary intermittent motion-picture mechanism to speeds much greater than ten times normal because of inherent mechanical difficulties. Thus, in general, it may be said that all types of high-speed cameras for speeds greater than about 160 pictures per second must utilize continuously-moving film instead of intermittently-moving film. There are two types of continuously-moving-film cameras:

(1) Those employing a moving optical system to keep the image stationary with respect to the film during the exposure time.

(2) Those employing an intermittent source of stroboscopic light whose flashes are of sufficiently brief duration to give a sharp image on the moving film.

Each of these two types of camera has its advantages and disadvantages which need to be carefully considered with respect to the particular problem at hand. The first type of camera[6,7,8] is especially adapted to the study of subjects which produce their own light, common examples of which are the burning of vapors, the action of explosives, the motions of an electric arc, the reactions in a photoflash bulb, and the behavior of the cathode spot in a mercury arc. The stroboscopic-light type of camera is of very limited use in the study of problems such as these.

The principal advantage of the stroboscopic-light type of camera over the moving-optical-system type is the short exposure time which effectively stops the motion of rapidly-moving objects during exposure. The stroboscopic light gives an exposure time of a few millionths of a second, which is considerably shorter than is feasible by the moving-optical-system method, especially since as long an exposure as possible is usually desired in the moving-optical-system type in order to get sufficient density on the film. In high-speed cameras employing stroboscopic light the film is moved past the lens at a constant speed, and each time the film has moved the distance occupied by one picture, the subject is illuminated by a short brilliant pulse of light. The time at which the flash occurs is controlled by a commutator rigidly attached to the film-driving mechanism, and the duration of the flash is so short that no appreciable blurring of the picture occurs. The particular type of stroboscopic-light, high-speed motion-picture camera developed at the Massachusetts Institute of Technology will now be described.

IV. The Source of Stroboscopic Light and the Camera

Condenser discharges into mercury-arc lamps have proved to be a very useful manner of obtaining stroboscopic light for photographic work. The light is actinic, the discharge time is short, the timing is susceptible to accurate control by means of pulse amplifiers, the con-

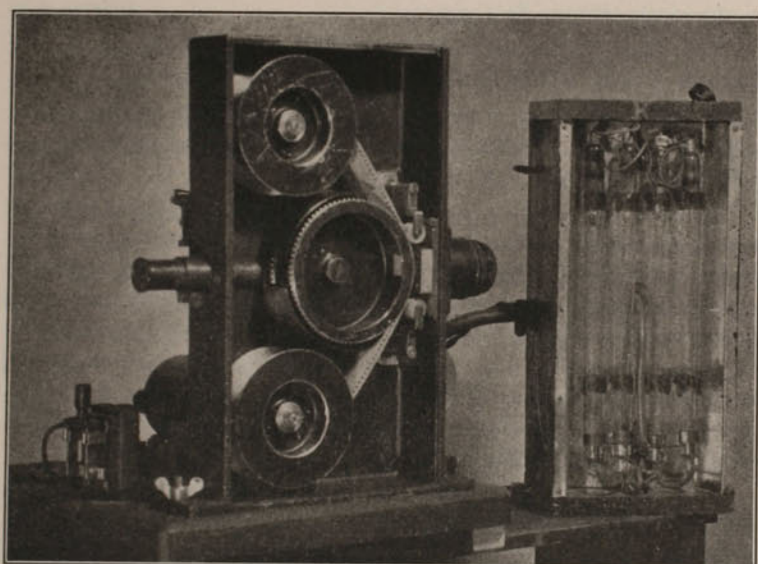


FIG. 3. A photograph of a continuously-moving-film, high-speed, motion-picture camera which takes 35-mm. pictures at speeds up to 1200 per second, and a bank of four mercury-arc lamps for providing the illumination.

struction of the tubes is relatively simple, and as many tubes may be connected in parallel as desired, since they all flash at the same instant.

Fig. 3 shows one bank of mercury-arc stroboscope tubes with four lamps, and the high-speed camera.

The wiring diagram of the apparatus in Fig. 3 for taking high-speed motion pictures is shown in Fig. 4. A six-phase, 10-kw. rectifier unit supplies 1000 volts d-c. to charge the condensers. Resistors in series with each condenser limit the flow of current to the lamp in

case of holdover, but still allow the con-
charged during the interval between flas

The lower part of the circuit shows tl
fier, which makes it possible for a sma
snap on the large mercury-arc lamps.
which go to the commutator trips the
discharge of the energy stored in the c
transformer T. The external starting l
may be connected in parallel, as shown,
be used for starting each tube or bank of

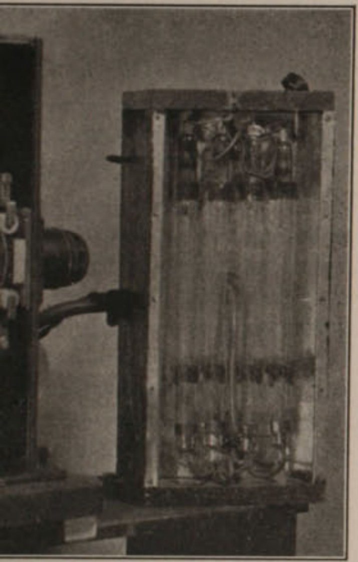
The camera shown in Fig 3 was pu
any sliding motion of the film against
scratches, heat generation, and electros
friction. The disadvantage of the typ
are taken upon the film while it is on
or not there is any appreciable distortio
of the sprocket and the size of the fra
also between a very large clumsy sproc
camera with its difficulties of acceleratio
its distortion. A consideration of these f
a diameter of approximately five inches
frames of film around its periphery.
of the picture is 0.0295 inch closer to th
upper and lower edges of the frame.
smaller for pictures shorter than the ful
square holes exactly the size of a 35-
placed in the sprocket for the purpose
and for critical focusing of the lens,
aid of a telescope located in the back
has been found to be very effective, sir
be easily and accurately checked just
Many subjects are very close to the ca
depth of focus is small.

Considerable care is required in the
tator, since the uniformity of framing
the commutator and brush rigging. A
the camera, the commutator is on the sa
is located outside the box in order to
construction is important, since any vib

[M]assachusetts Institute of Tech-

[Strobosc]opic Light and the Camera

[Mercu]ry-arc lamps have proved to be a
[st]roboscopic light for photographic
[disch]arge time is short, the timing is
[m]eans of pulse amplifiers, the con-



[...]sly-moving-film, high-speed, motion-
[...] at speeds up to 1200 per second, and
[...]iding the illumination.

[...]ple, and as many tubes may be
[...]hey all flash at the same instant.
[...]-arc stroboscope tubes with four

[...]atus in Fig. 3 for taking high-
[...]. 4. A six-phase, 10-kw. recti-
[...]arge the condensers. Resistors
[...] flow of current to the lamp in

case of holdover, but still allow the condensers to become effectively charged during the interval between flashes.

The lower part of the circuit shows the diagram of the pulse amplifier, which makes it possible for a small impulse from the brush to snap on the large mercury-arc lamps. Connecting the two wires which go to the commutator trips the thyratron and it permits the discharge of the energy stored in the condenser C into the step-up transformer T. The external starting bands of several of the tubes may be connected in parallel, as shown, or separate transformers may be used for starting each tube or bank of tubes.

The camera shown in Fig 3 was purposely designed to eliminate any sliding motion of the film against a gate or other parts, since scratches, heat generation, and electrostatic voltages are caused by friction. The disadvantage of the type shown is that the pictures are taken upon the film while it is on a curved surface. Whether or not there is any appreciable distortion depends upon the diameter of the sprocket and the size of the frame. A compromise is made also between a very large clumsy sprocket (and incidentally, a large camera with its difficulties of acceleration) and a small sprocket with its distortion. A consideration of these factors gave the main sprocket a diameter of approximately five inches with twenty standard 35-mm. frames of film around its periphery. For this sprocket the center of the picture is 0.0295 inch closer to the lens plane than the extreme upper and lower edges of the frame. This distance is naturally smaller for pictures shorter than the full 35-mm.-frame height. Two square holes exactly the size of a 35-mm. frame are diametrically placed in the sprocket for the purpose of alignment of the camera and for critical focusing of the lens, which is accomplished by the aid of a telescope located in the back of the camera. This method has been found to be very effective, since the focus and line-up may be easily and accurately checked just before the camera is started. Many subjects are very close to the camera, and for this reason the depth of focus is small.

Considerable care is required in the construction of the commutator, since the uniformity of framing depends on the perfection of the commutator and brush rigging. As shown in the photograph of the camera, the commutator is on the same shaft as the sprocket and is located outside the box in order to be readily inspected. Brush construction is important, since any vibration or bouncing will cause

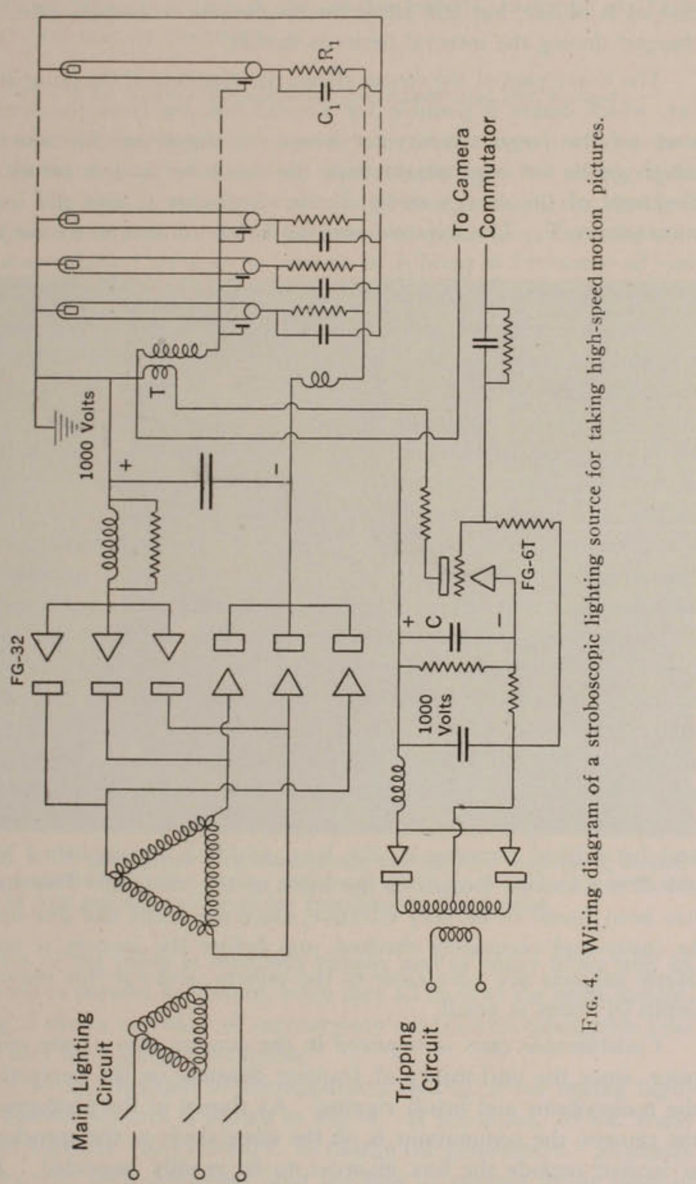


Fig. 4. Wiring diagram of a stroboscopic lighting source for taking high-speed motion pictures.

a non-uniform spacing of the frames. Th
copper brushes about 1/16 inch in diamete
the commutator by springs. Adjustment
tion of the frame with respect to the sp
mined. Since there is an inappreciable
circuit after the segment hits the brush
made with the camera at rest.

The driving motors have been selecte
and to hold fairly constant speed after th
A series motor is directly connected to th
of the camera. It is operated on overvol
accelerating torque so that it always te
The series motor contributes considerab
sprocket and to the supply reel, besides
reeling up the film as it comes through t
¼-H.P. induction motor is belted to the
A belt is used because of the ease of chang
pulleys. The motor is started with over
the acceleration torque. The speed-torqu
duction motor are such that the motor
speed corresponding to the speed of the
current in the armature windings. Since
acceleration period, the motor will run
speed, and the rate of taking the picture
and known. The film reaches a speed o
10 ft. of film.

V. Uses of the High-Sp

The most obvious use of the high-spe
tion pictures of fast or complicated motio
may be slowed down, when projected on
that the eye is able to see and the mind to
pictures may of course be projected repe
showings bring out details which were
projections.

The best speed of taking the pictures
tors, but in many cases pictures taken a
useful. A slow picture shows the slow
while a faster one shows more clearly t

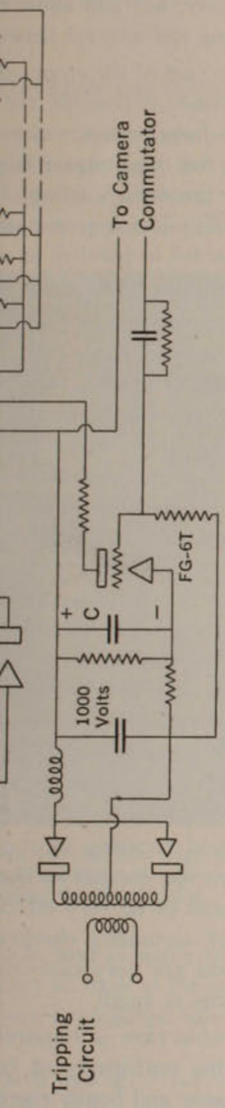


Fig. 4. Wiring diagram of a stroboscopic lighting source for taking high-speed motion pictures.

a non-uniform spacing of the frames. This camera has small stranded copper brushes about 1/16 inch in diameter. They are pressed against the commutator by springs. Adjustment is possible so that the location of the frame with respect to the sprocket holes may be determined. Since there is an inappreciable time lag in the electrical circuit after the segment hits the brushes, the brush adjustment is made with the camera at rest.

The driving motors have been selected to give rapid acceleration and to hold fairly constant speed after the film has been accelerated. A series motor is directly connected to the take-up reel at the bottom of the camera. It is operated on overvoltage in order to increase its accelerating torque so that it always tends to overdrive the film. The series motor contributes considerable acceleration to the main sprocket and to the supply reel, besides performing its function of reeling up the film as it comes through the camera. A three-phase, ¼-H.P. induction motor is belted to the camera shaft with a V belt. A belt is used because of the ease of changing speed by using different pulleys. The motor is started with overvoltage in order to increase the acceleration torque. The speed-torque characteristics of the induction motor are such that the motor tends to run at a constant speed corresponding to the speed of the rotating field set up by the current in the armature windings. Since the load is small after the acceleration period, the motor will run fairly close to synchronous speed, and the rate of taking the pictures is thereby fairly constant and known. The film reaches a speed of 75 ft. per second in about 10 ft. of film.

V. Uses of the High-Speed Camera

The most obvious use of the high-speed camera is for taking motion pictures of fast or complicated motions in order that that motion may be slowed down, when projected on the screen, to such a speed that the eye is able to see and the mind to comprehend. Such motion pictures may of course be projected repeatedly, and often subsequent showings bring out details which were not noticed in preceding projections.

The best speed of taking the pictures depends upon several factors, but in many cases pictures taken at several speeds also prove useful. A slow picture shows the slow part of an action in detail, while a faster one shows more clearly the faster part of an action.

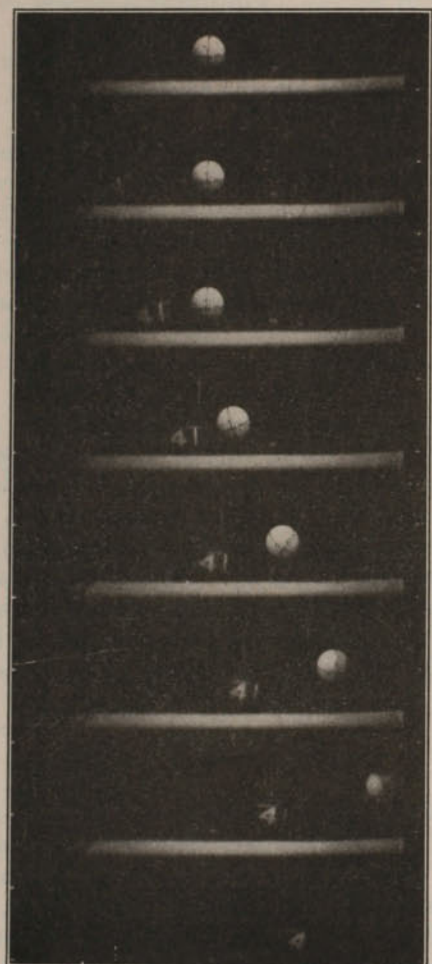


FIG. 5. High-speed motion pictures taken at 960 per second, of the impact of a golf club and ball for the purpose of measuring the velocities involved.

Take, for instance, a picture showing the
needle. Relatively slow pictures are used
of the needle, while pictures of much high
details of the stitching, since it occurs du
cycle. A rough but helpful calculation
deciding upon a speed for taking the p
speed of the motion is known, since the
projected action should be from three to

Another equally important use of the
camera is for obtaining engineering dat
individual frames on the moving-picture
time the instantaneous positions and the
photographed. In this respect the high-s
is for a mechanical engineer an instrume
graph for the electrical engineer, since
curves of current, voltage, and power as

The velocity of a moving object may b
picture film by measuring the difference
between two successive pictures and div
between the pictures. The accuracy of t
both by the accuracy of measurement o
accuracy of determination of the time in
introduces the larger inaccuracy because o
the displacement due to the small size of
exposure is long, and the size of the silve
as it becomes dry, and so the photograp
reference upon them in order that the resu
be independent of the state of the film.
determination is improved by taking clos
displacements between images. The short
boscopic light is especially advantageous
since the pictures are not blurred by m
exposure.

Acceleration measurements follow fr
tions, since the acceleration is the change
The slope of the velocity-time curve is the
the accuracy of measurement is dependen
measurement of velocity and time, with
measuring the slope of a curve.

on pictures taken
impact of a golf
ose of measuring

Take, for instance, a picture showing the action of a sewing-machine needle. Relatively slow pictures are used to show the general motion of the needle, while pictures of much higher speed are needed to show details of the stitching, since it occurs during a short portion of the cycle. A rough but helpful calculation may usually be made when deciding upon a speed for taking the pictures, if the approximate speed of the motion is known, since the desired time for the final projected action should be from three to eight seconds.

Another equally important use of the high-speed motion-picture camera is for obtaining engineering data and measurements. The individual frames on the moving-picture film record as a function of time the instantaneous positions and the form of the object being photographed. In this respect the high-speed motion-picture camera is for a mechanical engineer an instrument analogous to the oscillograph for the electrical engineer, since the oscillograph furnishes curves of current, voltage, and power as functions of time.

The velocity of a moving object may be measured from a motion-picture film by measuring the difference in the position of the image between two successive pictures and dividing by the time interval between the pictures. The accuracy of the final result is influenced both by the accuracy of measurement of the displacement and the accuracy of determination of the time interval. Usually the former introduces the larger inaccuracy because of the difficulty of measuring the displacement due to the small size of the pictures, the blur if the exposure is long, and the size of the silver grains. The film shrinks as it becomes dry, and so the photographs should have a distance reference upon them in order that the result of the measurement may be independent of the state of the film. The accuracy of velocity determination is improved by taking close-up pictures giving larger displacements between images. The short exposure time of the stroboscopic light is especially advantageous for velocity measurements, since the pictures are not blurred by motion of the object during exposure.

Acceleration measurements follow from the velocity determinations, since the acceleration is the change of the velocity with time. The slope of the velocity-time curve is therefore the acceleration, and the accuracy of measurement is dependent upon the accuracy of the measurement of velocity and time, with the additional difficulty of measuring the slope of a curve.

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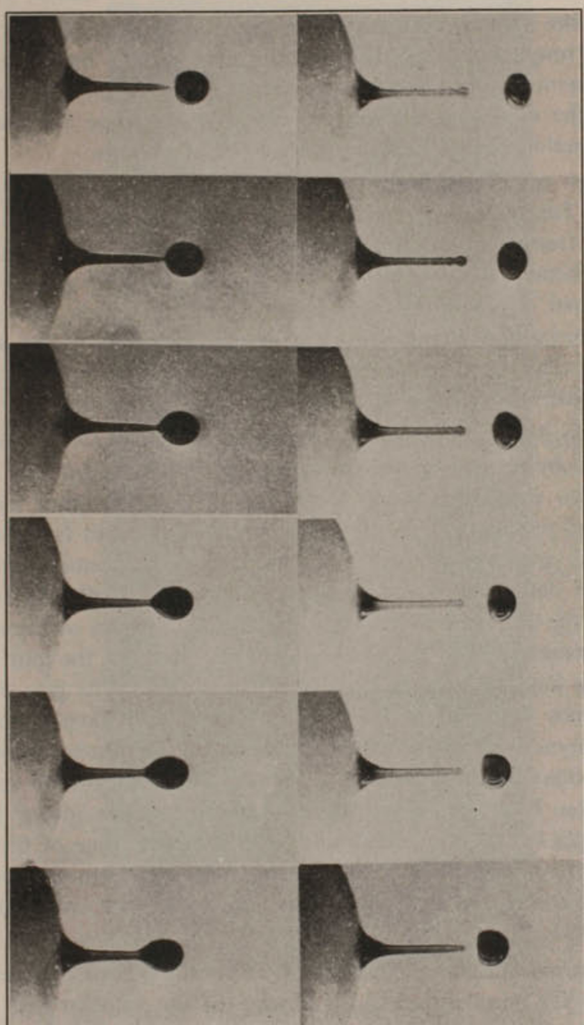

Fig. 6. A series of photographs taken from a high-speed motion picture (500 frames per second) showing the formation of a drop of water (slightly colored with ink) on the bottom of an electric-light bulb.

A very good example to illustrate the n
ties is the analysis of a golf stroke. Fig. 5
pictures taken at a rate of 960 per second.
and club are obtained by measuring the dis
and then multiplying by 960. Measure
means of a comparator permit the determ
the club and ball, both before and after i
about 2 per cent. An analysis of the p
resulted in the following data:

Initial club velocity just before im
Final club velocity just after impa
Ball velocity ....
Spin of the ball ....

Since the mass of the ball and the club
information to calculate the energy lost
energy gained by the ball, as well as to
in rotation. The pictures show definitel
in actual contact for less than 1/1000th c
occurs during the interval between pictur

VI. The Application of High-S
to Chemical Engin

The applications of the stroboscope
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fields of engineering, but there are cas
should be useful. A few possibilities ar
are the outcome of suggestions by chemica
cations may occur to the reader. Many of
cal in nature, but they are intimately tied u
processes.

In chemical engineering there are so
machines. The first type to consider are
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the travel and behavior of crystals and c
of a rapidly-rotating centrifuge. This s
problems of centrifuge design. Similarl
by centrifugal means could be studied.

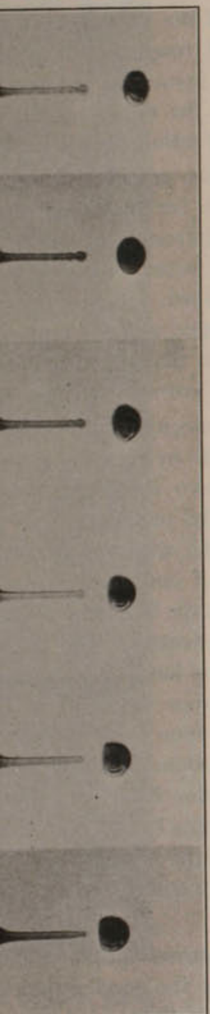

Fig. 6. A series of photographs taken from a high-speed motion picture (500 frames per second) showing the formation of a drop of water (slightly colored with ink) on the bottom of an electric-light bulb.

A very good example to illustrate the method of measuring velocities is the analysis of a golf stroke. Fig. 5 is a series of instantaneous pictures taken at a rate of 960 per second. The velocities of the ball and club are obtained by measuring the displacement between pictures and then multiplying by 960. Measurements of displacements by means of a comparator permit the determination of the velocities of the club and ball, both before and after impact, with an accuracy of about 2 per cent. An analysis of the photograph shown as Fig. 5 resulted in the following data:

Initial club velocity just before impact ..	151 ft./sec.
Final club velocity just after impact	114 ft./sec.
Ball velocity	186 ft./sec.
Spin of the ball	5000 r.p.m.

Since the mass of the ball and the club are known, there is sufficient information to calculate the energy lost by the club-head and the energy gained by the ball, as well as to calculate the energy stored in rotation. The pictures show definitely that the ball and club are in actual contact for less than 1/1000th of a second since the impact occurs during the interval between pictures.

VI. The Application of High-Speed Photography to Chemical Engineering

The applications of the stroboscope and the high-speed camera are probably not as extensive in chemical as they are in certain other fields of engineering, but there are cases where these instruments should be useful. A few possibilities are enumerated below, which are the outcome of suggestions by chemical engineers, and other applications may occur to the reader. Many of these problems are mechanical in nature, but they are intimately tied up with chemical-engineering processes.

In chemical engineering there are some cases of very high-speed machines. The first type to consider are those depending on centrifugal force. High-speed photography should enable one to study the travel and behavior of crystals and other materials in the basket of a rapidly-rotating centrifuge. This study should help in solving problems of centrifuge design. Similarly, the breaking of emulsions by centrifugal means could be studied. Lines of flow, dead spaces, etc. in centrifugal pumps also could be studied in this way and should help in designing better pumps.

Vibration problems are another type where high-speed photography is valuable. These fall into two groups: first, where vibration is desirable and is to be utilized to the greatest possible extent; second, where vibration is undesirable and should be prevented as far as possible. In the first group there are many examples, such as motion and formation of fibers on a vibrating wire of a paper machine, motion of ground particles on a vibrating screen for sifting, motion of particles on a vibrating table for ore classification, behavior of liquids subjected to sonic or ultrasonic vibration, etc. In the second type the information obtained by photographs should help in eliminating undesirable vibrations.

Colloid mills are a type of very-high-speed equipment. Here special mills would have to be built with transparent plates and housing. High-speed photographs of materials passing through such mills should give very valuable information concerning the action of such mills.

Vane pumps are slower-acting, but a study of such pumps, built with transparent sides, would give valuable data on how the vane follows the wall. Such data would be very useful in designing pumps.

One very common problem in chemical engineering which lends itself particularly to high-speed photography is that of getting intimate contact between a liquid and a gas. This problem arises in many places and in many forms, such as in sprays which are used to obtain intimate mixtures of fuels and air for combustion; for obtaining intimate mixtures of water with air for cooling, washing, or humidification; for obtaining intimate mixtures of a liquid and a gas which are to react. Foams, bubbles, and froths such as are used in fractionating towers to obtain intimate mixtures of ascending vapors and descending reflux liquid, in absorbers to obtain intimate contact between the gas and the washing liquid, etc., present similar problems. The formation, travel, and bursting of the gas bubbles and the travel of the liquid could be studied by means of high-speed photography. While considering the question of bubbles, foams, and froths, it is desirable to consider the study of their formation and utilization in the floatation of ores, in firefighting, and in beverages.

The problem of rupture is of great importance to chemical engineers, particularly brittle rupture. This again comes under two heads:

* Assistant Professor of Electrical Engineering, Massachusetts Institute of

first, where rupture is desired, as in crusl
where resistance to rupture is desired, as
factured materials. In the case of brittl
very suddenly with but little previous de
happens at the instant of rupture can be
speed photography. This photographic s
tell the amount of deformation taking p
directions of rupture, cleavage planes, etc.
at rupture. This knowledge should enabl
design mills and crushers to get the maxin
expended, to design brittle equipment
quartz, enamels) so as to get the maximu
to study various materials to see which wo
types of strain or impact.

The problem of elastic and plastic de
resilient materials is similar to that of
of such materials is constantly becoming
its compounds, synthetic resins, and ot
percha, and others. A photographic stu
impact would no doubt give a valuable
various purposes.

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   tains other references.)
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   ary, 1928. Trans. Soc. Motion Picture
   ber, 1926.

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phy is that of getting intimate
problem arises in many places
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ustion; for obtaining intimate
washing, or humidification;
quid and a gas which are to
as are used in fractionating
cending vapors and descend-
intimate contact between the
similar problems. The for-
bubbles and the travel of the
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and utilization in the floata-
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importance to chemical engi-
again comes under two heads:

ering, Massachusetts Institute of

first, where rupture is desired, as in crushing and grinding; second, where resistance to rupture is desired, as in the case of most manufactured materials. In the case of brittle materials rupture comes very suddenly with but little previous deformation. Exactly what happens at the instant of rupture can be determined only by high-speed photography. This photographic study would enable one to tell the amount of deformation taking place just before rupture; directions of rupture, cleavage planes, etc.; general behavior of body at rupture. This knowledge should enable one more intelligently to design mills and crushers to get the maximum rupture for the energy expended, to design brittle equipment (glass, ceramic materials, quartz, enamels) so as to get the maximum resistance to rupture, and to study various materials to see which would best withstand different types of strain or impact.

The problem of elastic and plastic deformation under impact of resilient materials is similar to that of rupture. The manufacture of such materials is constantly becoming more important, rubber and its compounds, synthetic resins, and other molded plastics, gutta percha, and others. A photographic study of these materials under impact would no doubt give a valuable check on their fitness for various purposes.

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Notebook Number: T-4

Scanning and Separation Record

____unmounted photograph(s)

1 negative strip(s)

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

was/were scanned where originally located between page 110 and 111.

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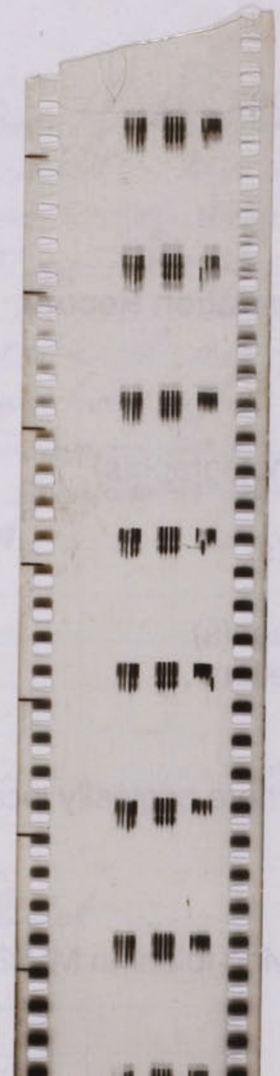
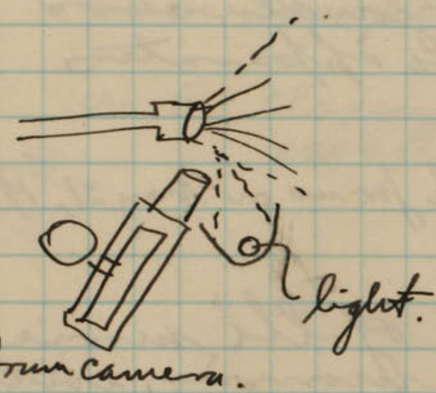
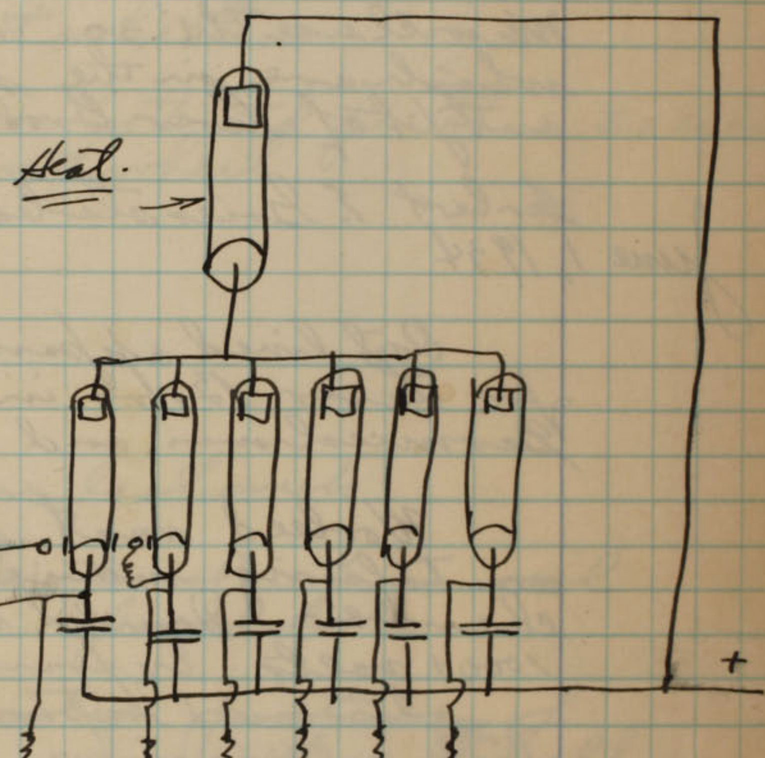


May 31, 1934
H.E. Edgerton.

I came to New York last night and spent most of the day with Mr. Davis, Mr McAuley and Mr. Hogney discussing my work ~~with~~ of last summer ~~at the~~ on the problem at the Lever Brothers Plant. There is some possibility of doing further work. I suggested the use of a series of flashes, for instance six or 8 on a continuously moving film. Photographs by ~~continuous~~ direct illumination would be best.





Trip cold lamps in succession with a commutator on the ~~film~~ camera. use drum camera.

120 x 50 = 6000 per second

Increase voltage until trailer disappears.

May 31, 1934

Discussed more high speed movies with Mr. Bodman, Mr Stevenson, Mr Pease in the aft as a result of Mr. Hogueys letter. We are to go ahead.

Proposed program.

6 flash pictures showing close-ups by reflected light of particle formation from Rinso Production nozzles.

We will use the 30 12 uf condensers which are in the spark apparatus outfit of Lever Bros.

Herbert E. Grier started work for us on May 31, 1934.

June 1, 1934

Outlined apparatus of the movie for Lever Bros in the morning with Germeshausen and sent off orders.

Worked rest of day with Dorfield ~~on~~ taking movies of a cloud expansion chamber. Donut shaped tube 2 uf. 1000 + volts. Exposure weak.

Increased capacity to 4 uf to get better exposure.

A picture taken at 420 per second showed that about 1/10 of a second elapsed before the tracks appeared and that about 1/100 of a second brought out full development of the tracks.

Dr. Eliot Hubbard brought over some fighting cocks and we took movies (700/sec) and stills with the spark. Some came out fine. (on May 31.)

June 3, 1934
H.E. Edgerton.

Yesterday I worked with Germeshausen and Grier on the Waterbury - Ingersoll watch movements brought up by Mr. Putman. Extension lens mount made for lens.

taken with f 1.4 lens 5 cm. 35 mm	No 1. Test exposure.	2 x enlargemen
	No. 2. Balance wheel springs	
	No. 3. Ballance wheel and arm.	
	No. 4. Escapement wheel.	
taken with f 1.4 lens 1" focal length. (16 mm) lens.	No. 5. closeup of one tooth and pin on escapement wheel.	3 x enlag.

June 11, 1934.

We took many pictures last week!

Assembled cavitation material into a reel on Friday with Peters. Spannhake.

took Stroboscopic motion pictures of the vibrations of the wings of a small model airplane in the small wind tunnel in the Hangar.

Took enlarged movies of tearing of paper 4x enlargement using 1.4 lens, 1" focal length.

Grier increased enlargement to 20 times still using positive film. 2 mf 1000 V discharge through a spark gap.

On this ? (also Wed) day I worked with Swarty of the textile department trying to take movies

Notebook Number: T-4

Scanning and Separation Record

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2 negative strip(s)

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

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

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

showing the mercerizing process whereby an 18 percent alkali solution is put on a cotton fiber. The fiber swells up.

Pictures taken 500 per second on 16 m m film at 60 diam enlargement. Sample below in envelope.

Notebook Number: T-4

Scanning and Separation Record

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1 negative strip(s)

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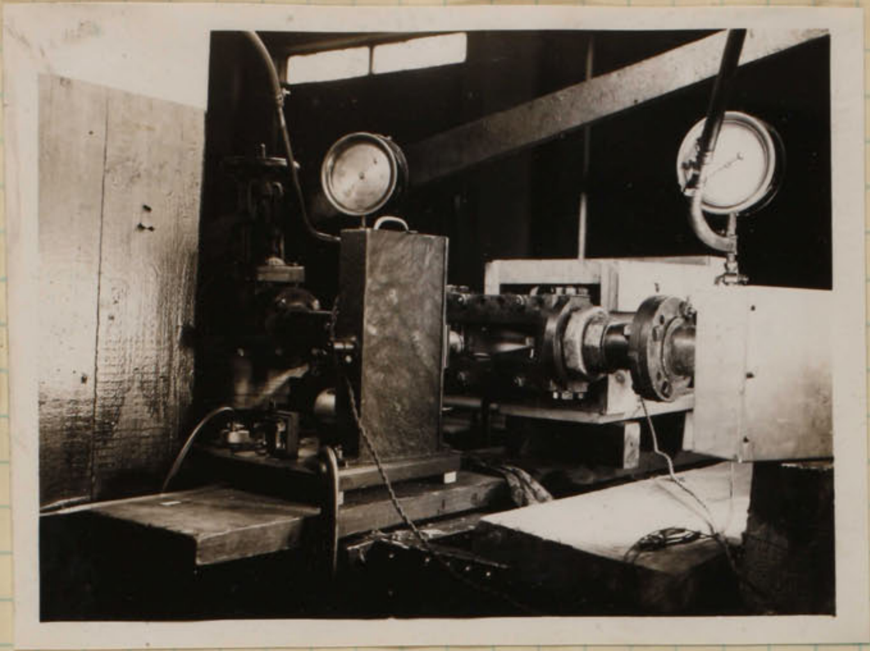
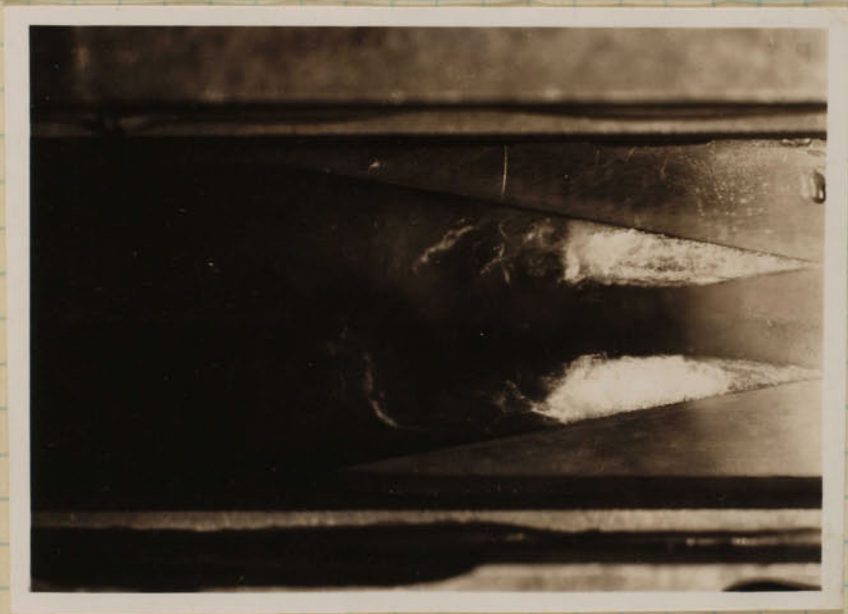
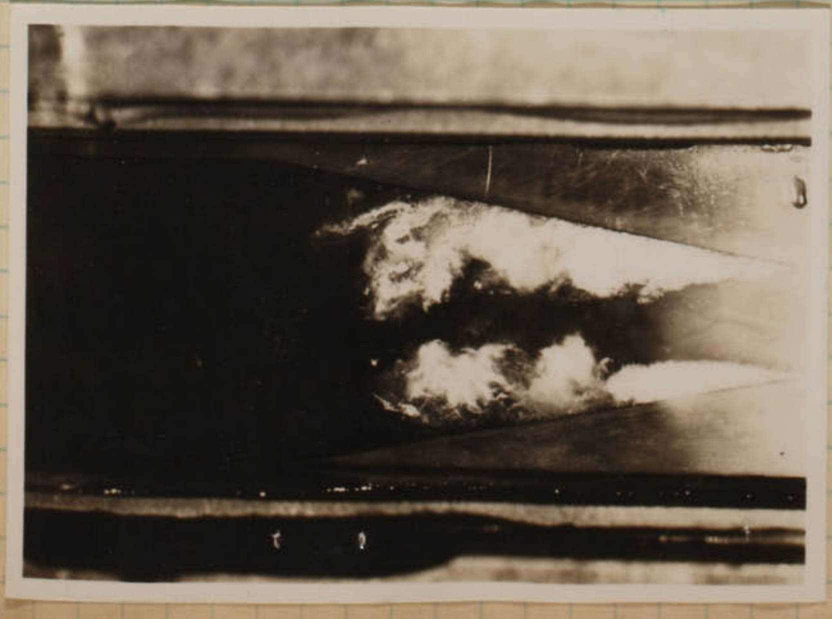
NITRATE FILM



Small cavitation apparatus.

movies on p 108





1. <u>Cavitation Research at the Massachusetts Institute of Technology</u>
June, 1934

2. Cavitation is produced in a Venturi-shaped passage which has glass sides permitting photographs to be taken.

   A. Scene showing Spannhake and Halberg working on the large cavitation apparatus.

3. A close-up of the test section.

   B. Scene of Venturi in action as seen with an ordinary moving-picture camera.

4. It is impossible for the eye to follow the rapid motion.

5. An instantaneous photograph shows white clouds.

   C. A 10-second still showing a spark photograph.

6. High-speed motion pictures show the white clouds forming periodically.
(Silhouette pictures at 500 per second)

   D. High-speed movies of plungers.

7. The collapse also is periodic.
(1500 pictures per second) (2)

   E. More movies of cavitation, but down stream.

8. A smaller unit also shows the periodic nature of cavitation.

   F. Scene showing high-speed camera in front of the small apparatus.

   G. Ordinary pictures of the cavitation.

9. High-speed motion pictures showing half of the Venturi.
(3000 pictures per second)

   H. High-speed movies. (3)

10. The frequency has been found to be a function of the velocity of the water and the length of the cavitation.

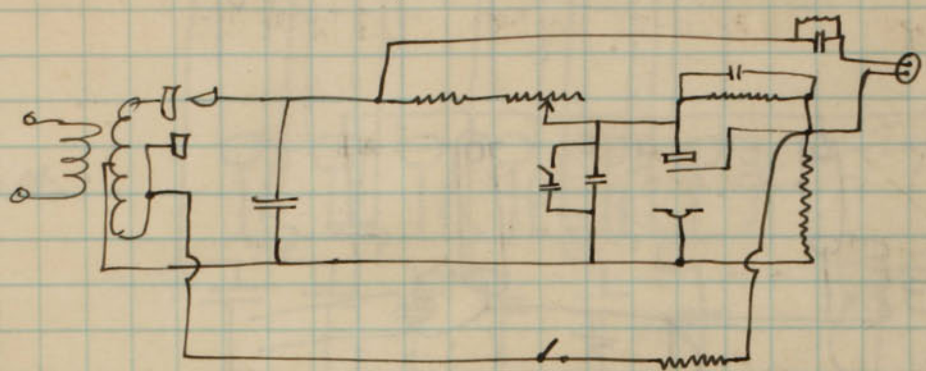
Repeat H.

Finis.

H. E. Edgerton
H. Peters
June 11, 1934

June 11 1934
H. E. Edgerton.

Circuit for Neon Oscillator Stroboscope.



Discussed with K. J. Germeshausen.

Proposed arrangement for G.R. Stroboscope.

Two switches
1. Extra range
2. 60 cycle

60 cycle switch.

Another method of 60 cycle. – a switch to cut off the filter would make 120 cycle interruptions possible.

June. 15, 1934.

We have been doing a lot of experimenting the last few days with sparks, mercury lamps etc for the Lever Bros Co. This is preliminary work towards the flash outfit for taking 6 pictures at 6000 a second showing the formation of soap from a nozzle and of the formation of other material from nozzles of different kinds.

Factors influencing flash. duration.

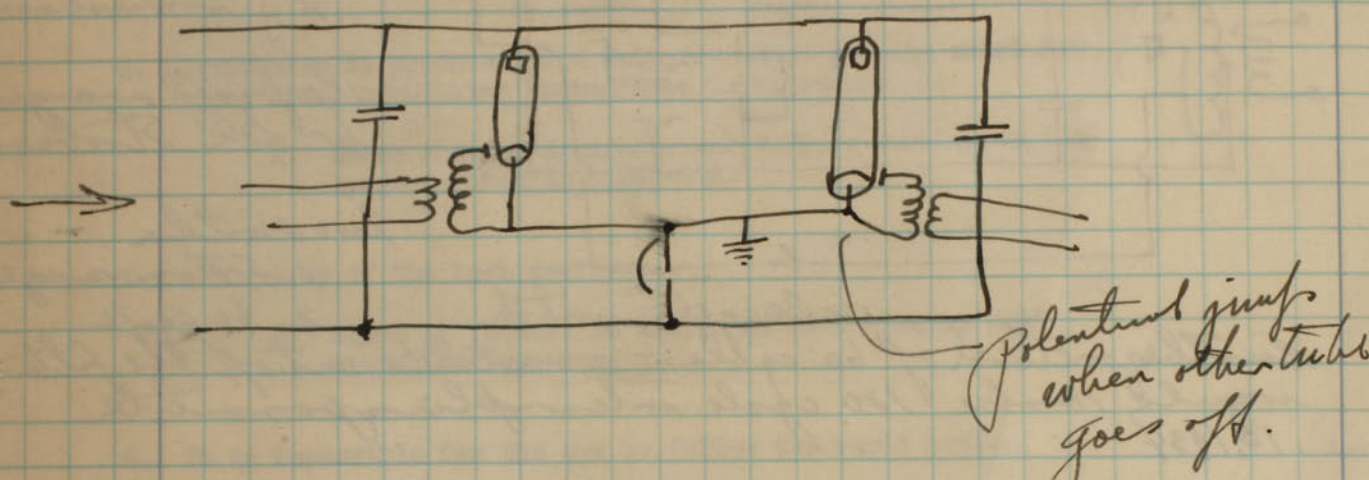
1. Length of leads.
2. Size of capacitor
3. Voltage.
4. Loose contacts.

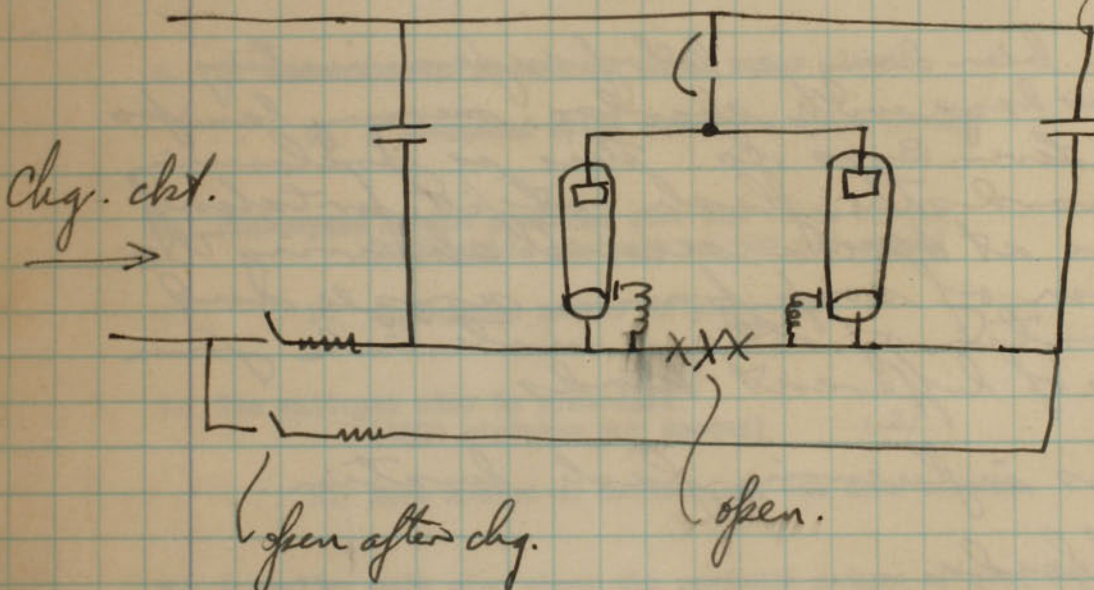
1 microfarad charged to 14000 volts and discharged through a 1/4" brass gap in series with a Hg lamp. (30 mm diam 12" long) gives a short flash. Test. 1:1 picture of small spots on a 16 inch disc going 3600 r.p.m (251 ft/sec.) is undiscernable.

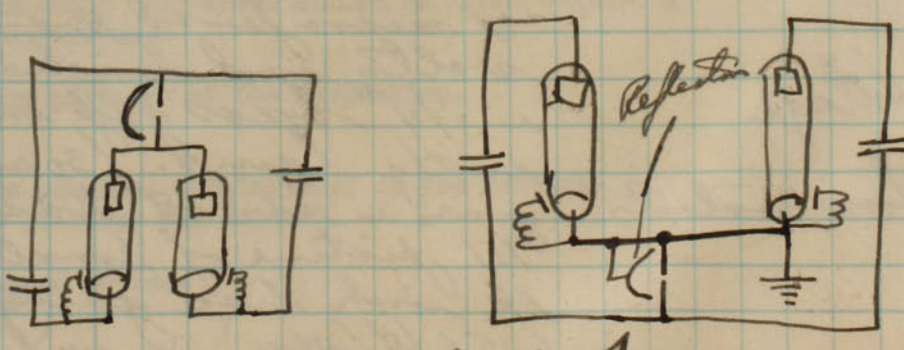
With 3 uf at the same voltage the trailer just comes up. A loop of wire 15 inches in diam introduces enough inductance to cause a change in definition.

June 15, 1934.
Harold E. Edgerton
with Grier
Germeshausen.

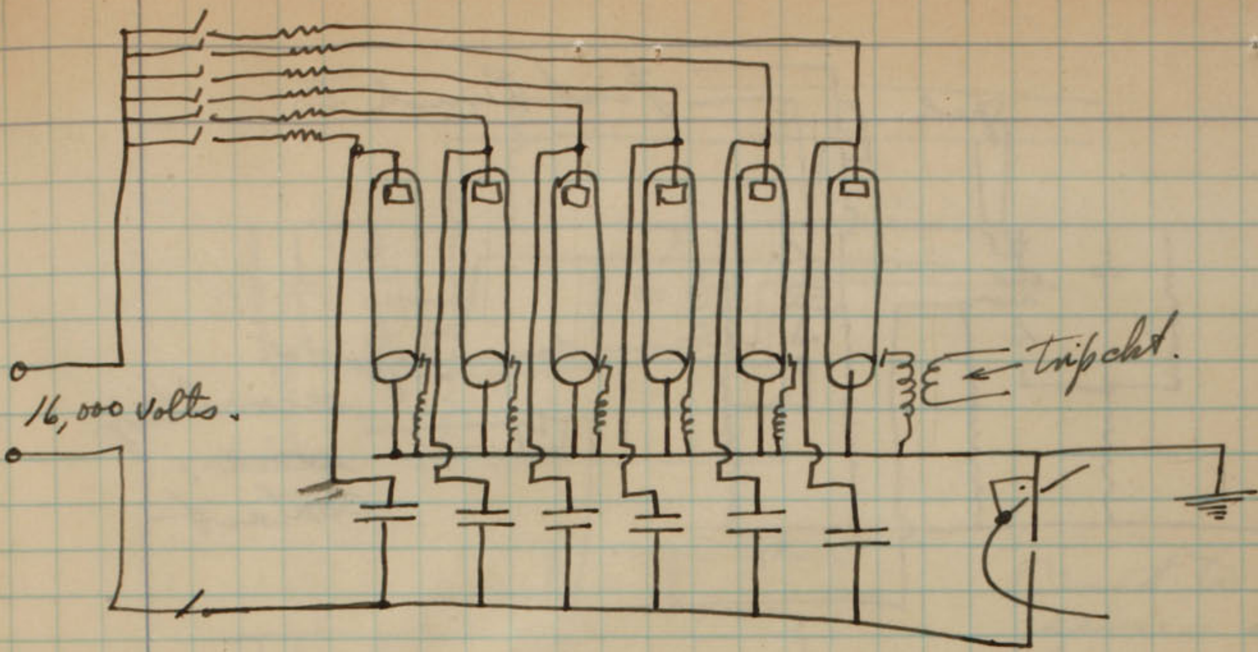
Camera for taking series of pictures.



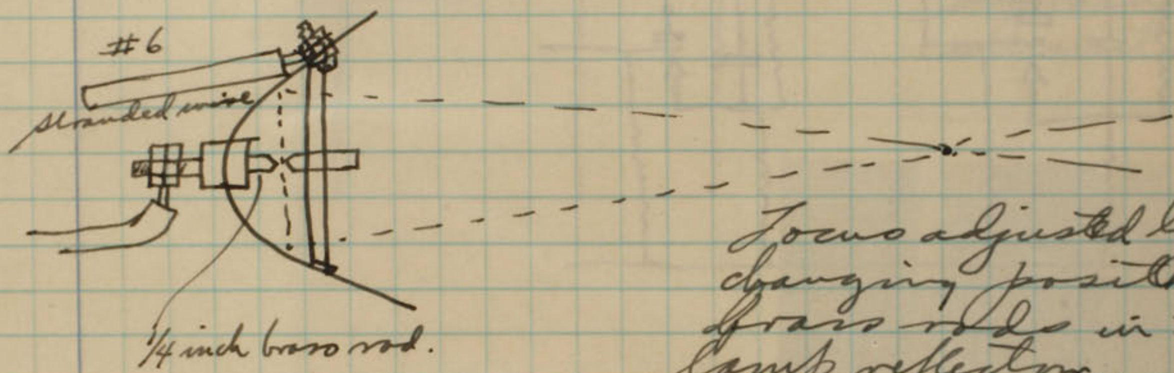




This ckt looks best →
since the cathodes are grounded
also one side of the spark coil and
the gap.

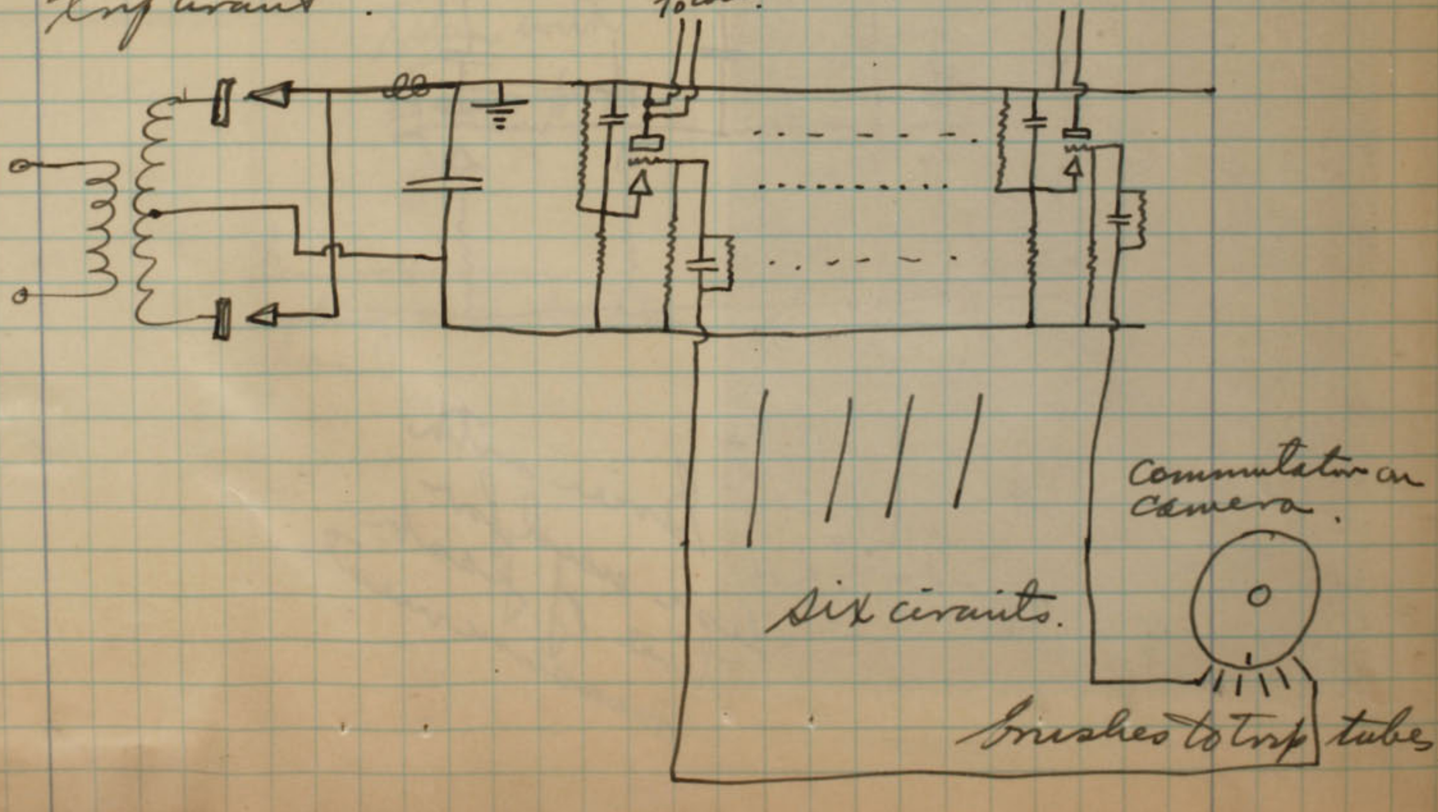


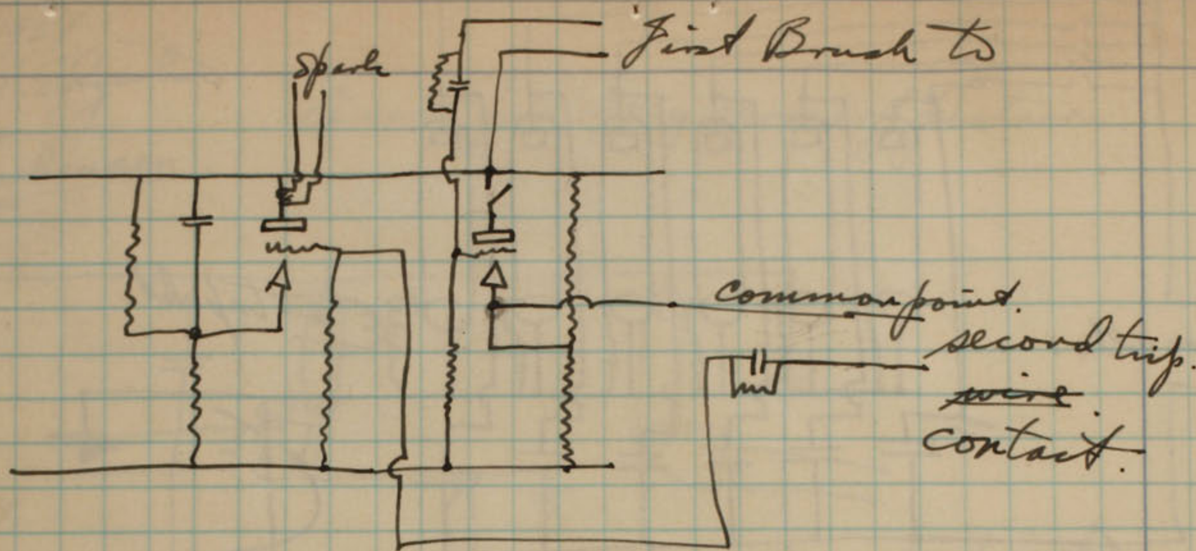
Construction of the reflector is
as shown below and it works very well

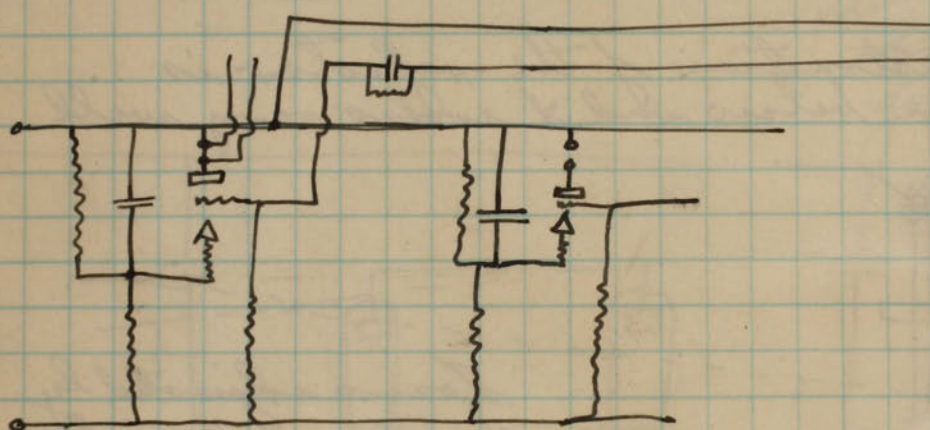


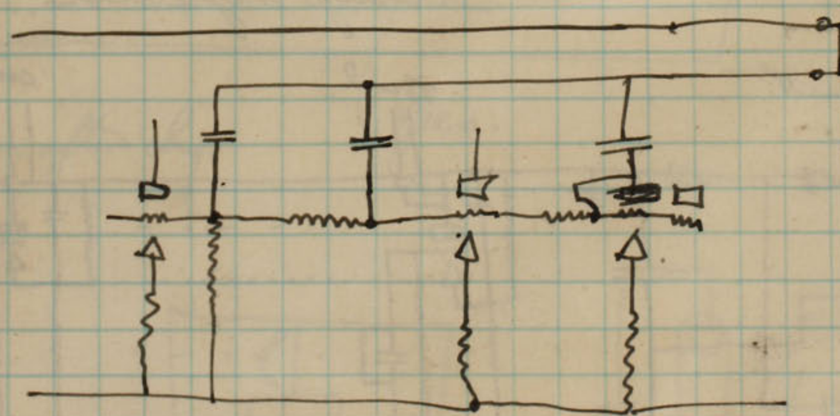
Focus adjusted by
changing position of the
brass rods in the
lamp reflector..

Trip circuit.

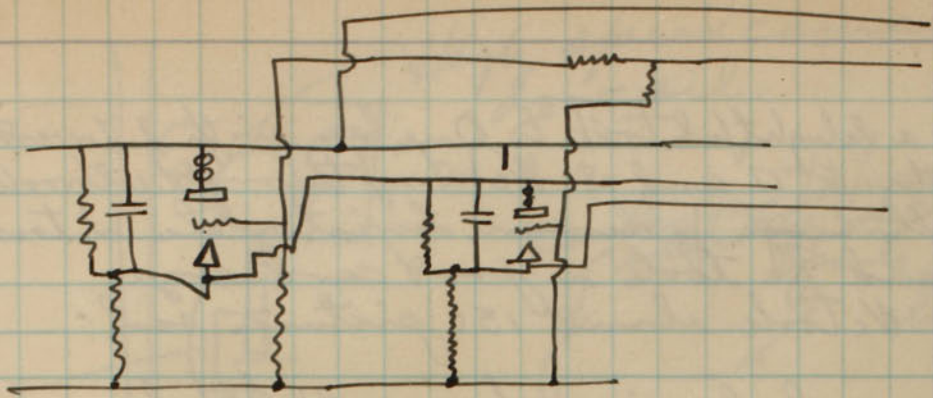


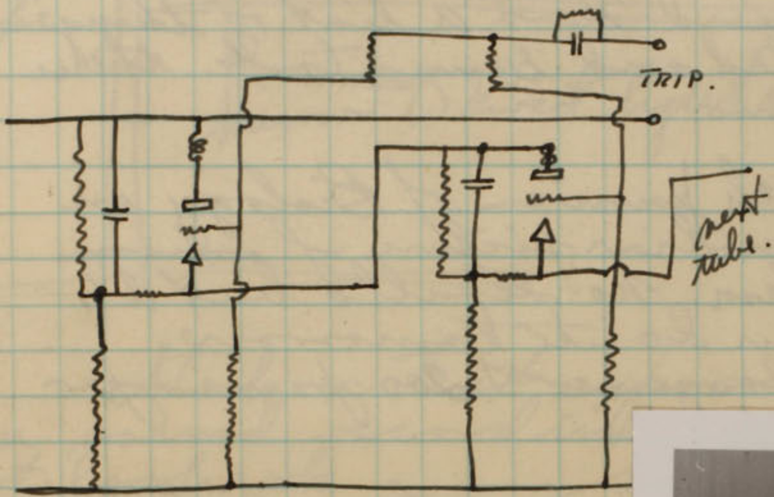






10-211A. H.S. Grier with tape used for time of flash measurements.





Circuit to trip a series of thyratrons from a common pair of brushes and multiple segments on the commutator.

taken with Leica ~~afont~~ June 15.

Germeshausen working on stroboscopic tubes.

June 20 1934.
H E Edgerton.

I had a delightful trip to Quebec with J Forrest Pease on the 16 17 and 18. Went up through colbrook returned through Jackman, Lewiston etc. I took a Leica and he took a post card size Graflex. We took about 150 pictures each!

Discussed design of small stroboscope with Germs and Herb. A list of things were suggested and Germs took them over to Wilkins.

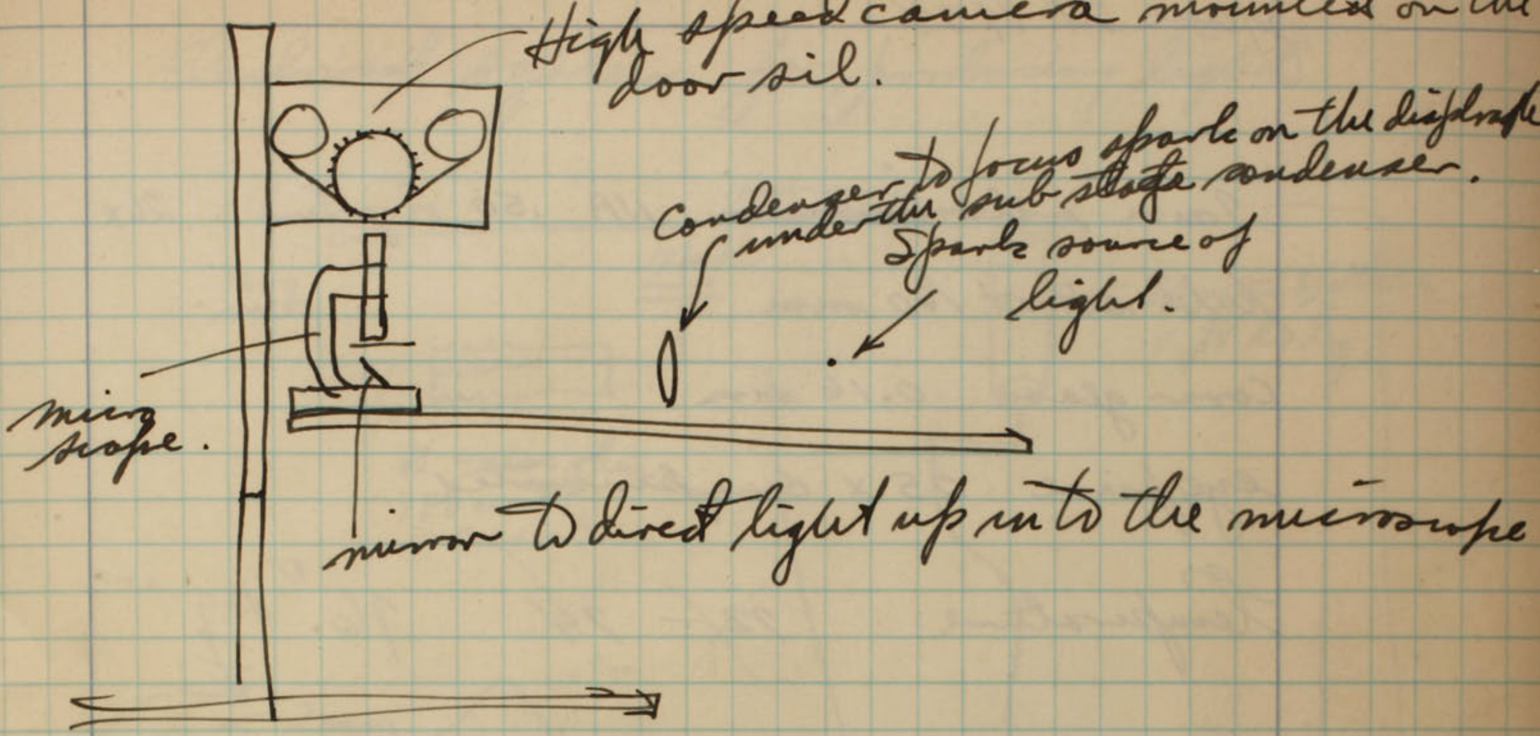
Worked with Jennison of Biology on high speed motion pictures of ~~cilian~~ cilia in a clam. No results but I think we can do it tomorrow. 500 diam enlargement 200 frames per second.

Started layout of material for the Lever Bros. job. The motor for the camera returned and will be assembled soon.

June 23 1934.

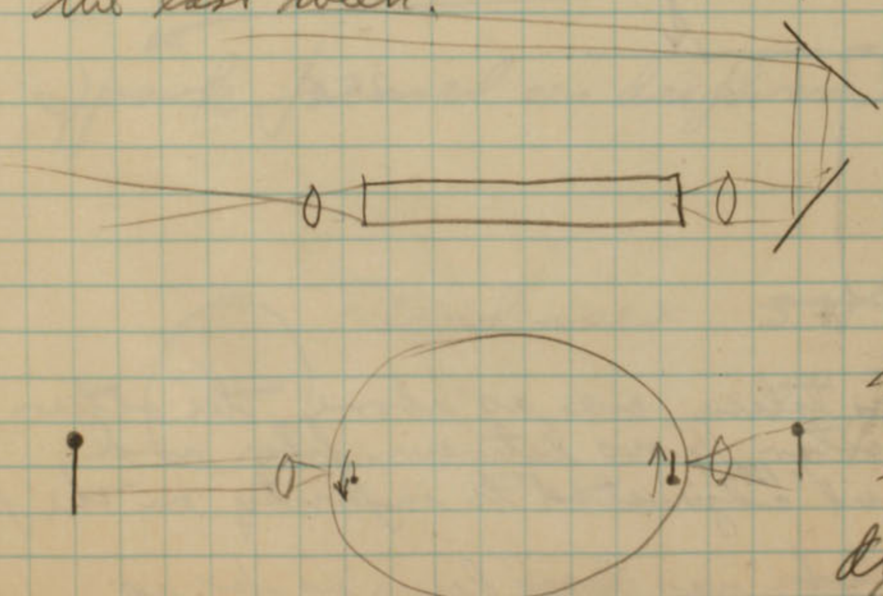
Prof Bunker of Biology Dept came down yesterday in the aft bringing Jennison & Hardy to discuss the layout for taking high speed motion pictures through the microscope.

We tore down the old set up and set up an optical arrangement suggested by Prof Hardy.



I took a test exposure this morning on sound recording positive film and it looks o.k.

June 28 1934 We have worked a lot upon the biology work the last week!



Scheme for lighting photography.

A lens on both sides of the camera.

Mirrors to direct both in the same direction.

June 28 1934

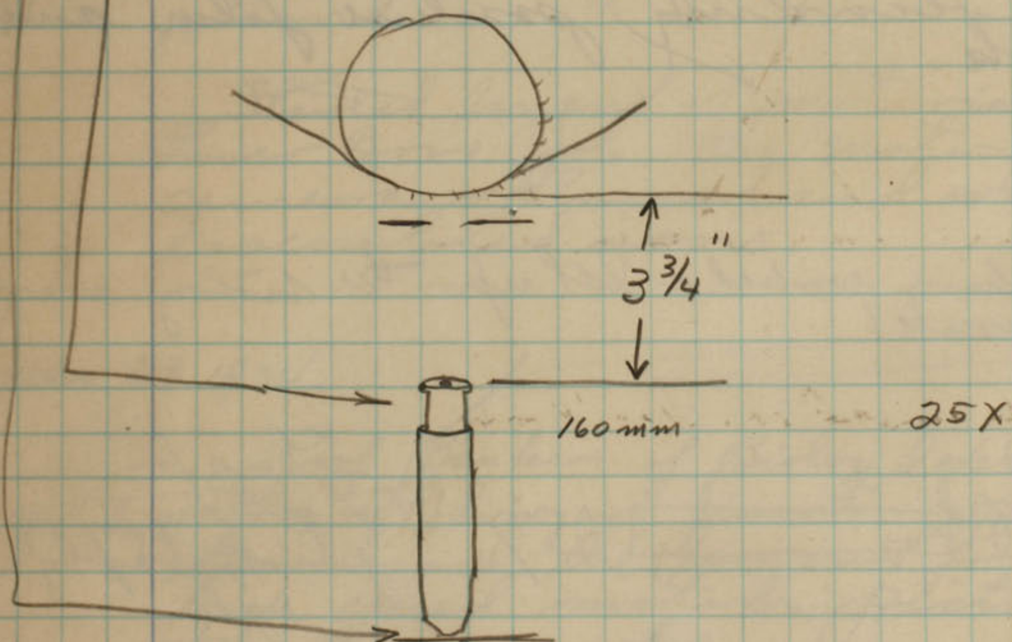
1 mm water ~~immersion~~ immersion NA .50 objective 26x

tube set at 160 mm

Cover glass 0.16 mm

eyepiece 25 x compensated.

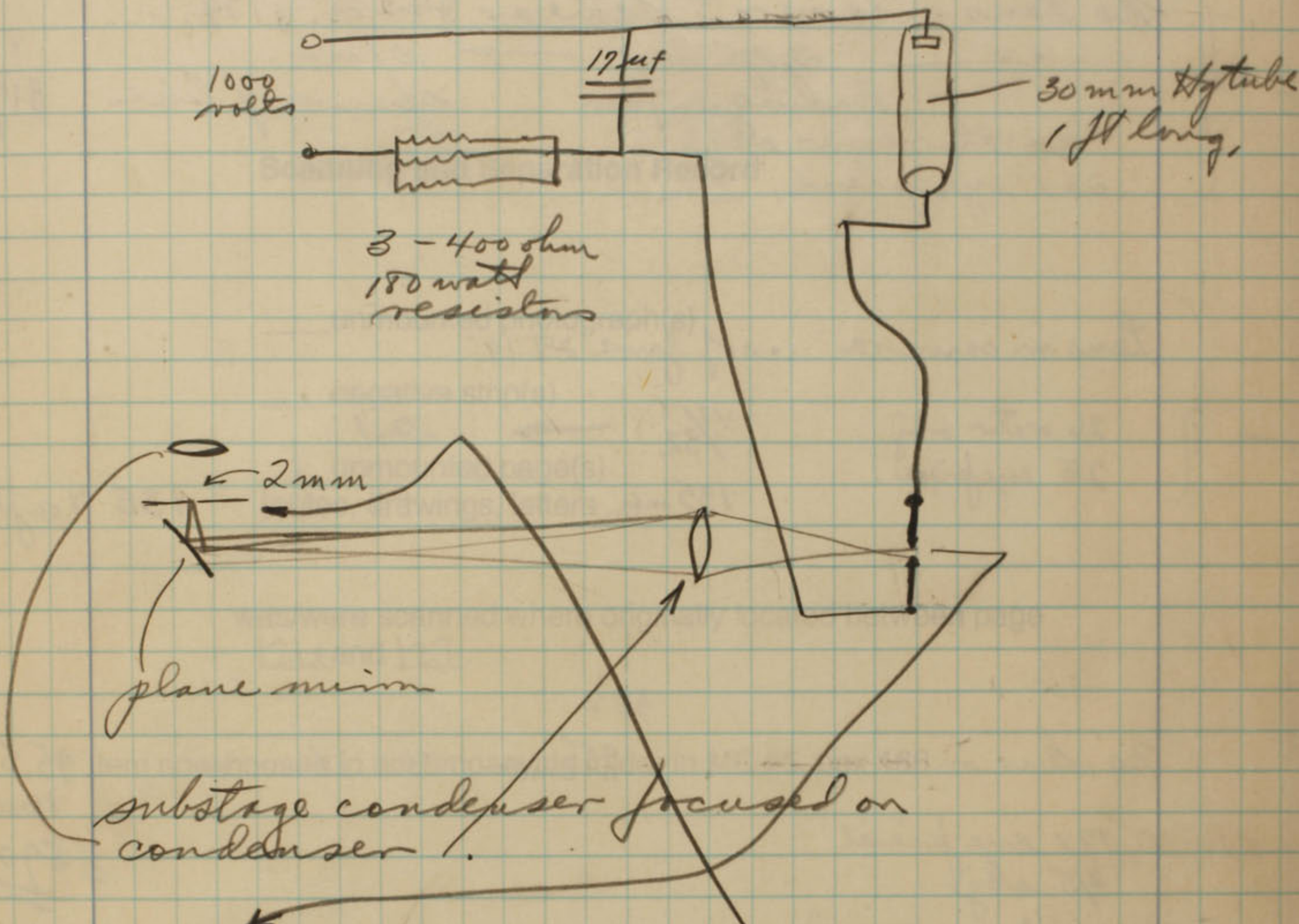
Temperature ~~72 - 74~~ 76° degrees F.

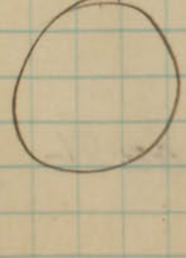


Two pictures taken, one as above, the other with a Biotar lens between film and eyepiece and 1:1.4 adjusted to infinity on the film.

The diaphragm was closed down as far as possible, Opening about 1/2 mm.

Electrical system for producing light.





Condenser. 3.3/4" diam

8" focal length ± .5 inch.

July 9. 1934
H E Edgerton
Jennison

Enlargement meas.

{ no Lens in camera same as June 28. p 124.
. . 3.175 mm ⟶ .01 mm.
Reading on film spacing of lines 317.5 x
26 water emer obj.
25 x eye piece. }

{ Lens in camera as of June 28 19
26 water obj 17/32 ⟶ 0.1
25 eyepiece. 13.5 mm 0.1 135 X on film }

3/8" x
no Lens in camera .955 mm ⟵ .1 mm. 95.5
x 6 enlarg.
10 x eye piece = 570
45 obj. enlargement
Condition as used in movies for enlargement.

hair = 3/4" 19 mm $\frac{19.}{570}$ $\frac{6}{7}$ = .0286 length.

$\frac{1}{16}$. .0024 mm diam.

Notebook Number: T-4

Scanning and Separation Record

____unmounted photograph(s)

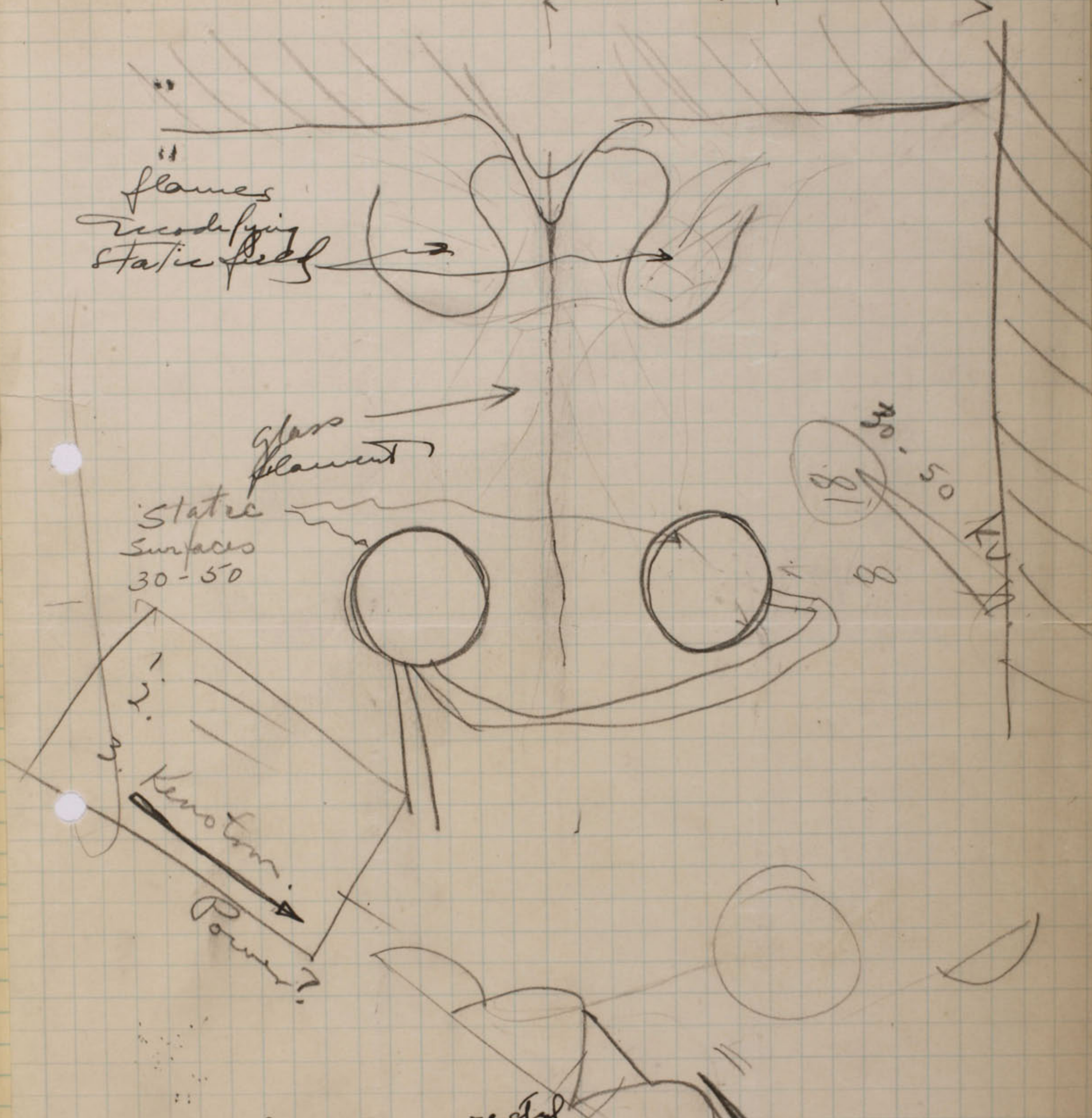
____negative strip(s)

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

was/were scanned where originally located between page 126 and 127.

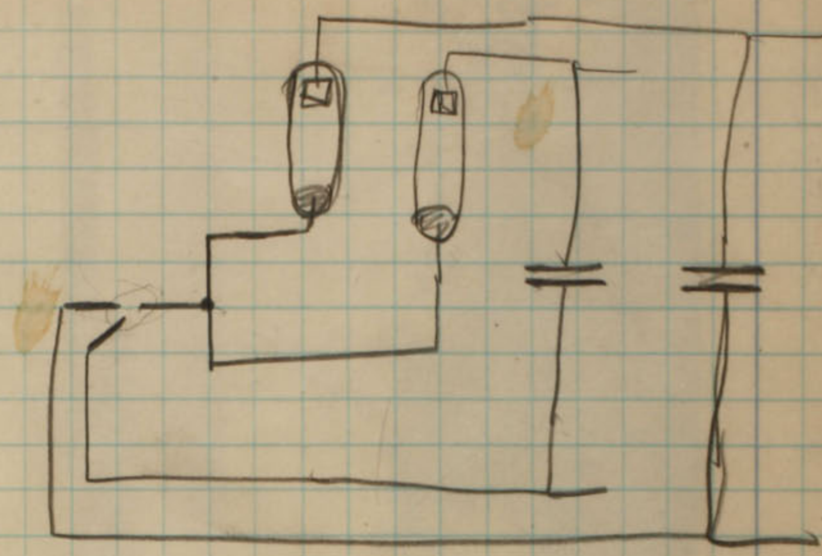
Item now housed in accompanying folder in MC 25, box 166

file owens Dll.
C. 49,672 (with a "6" written above the "6")



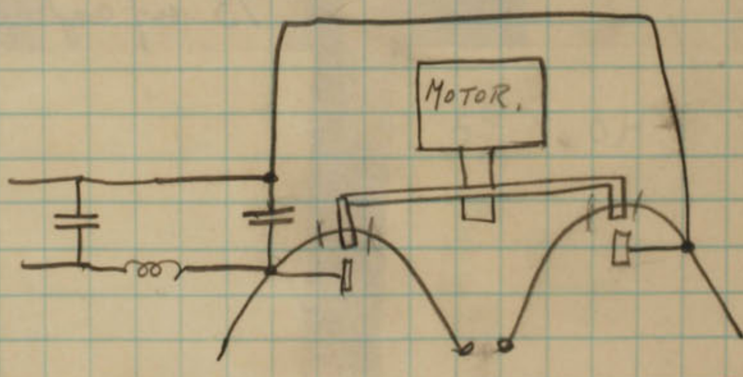
Sketch by corrected wave
Harold
Dr. Lloyd Egerton Dec 11th
Nov 28 1933

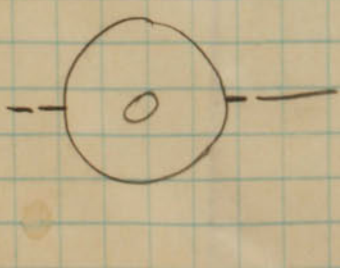
Witness B. B. Fogler

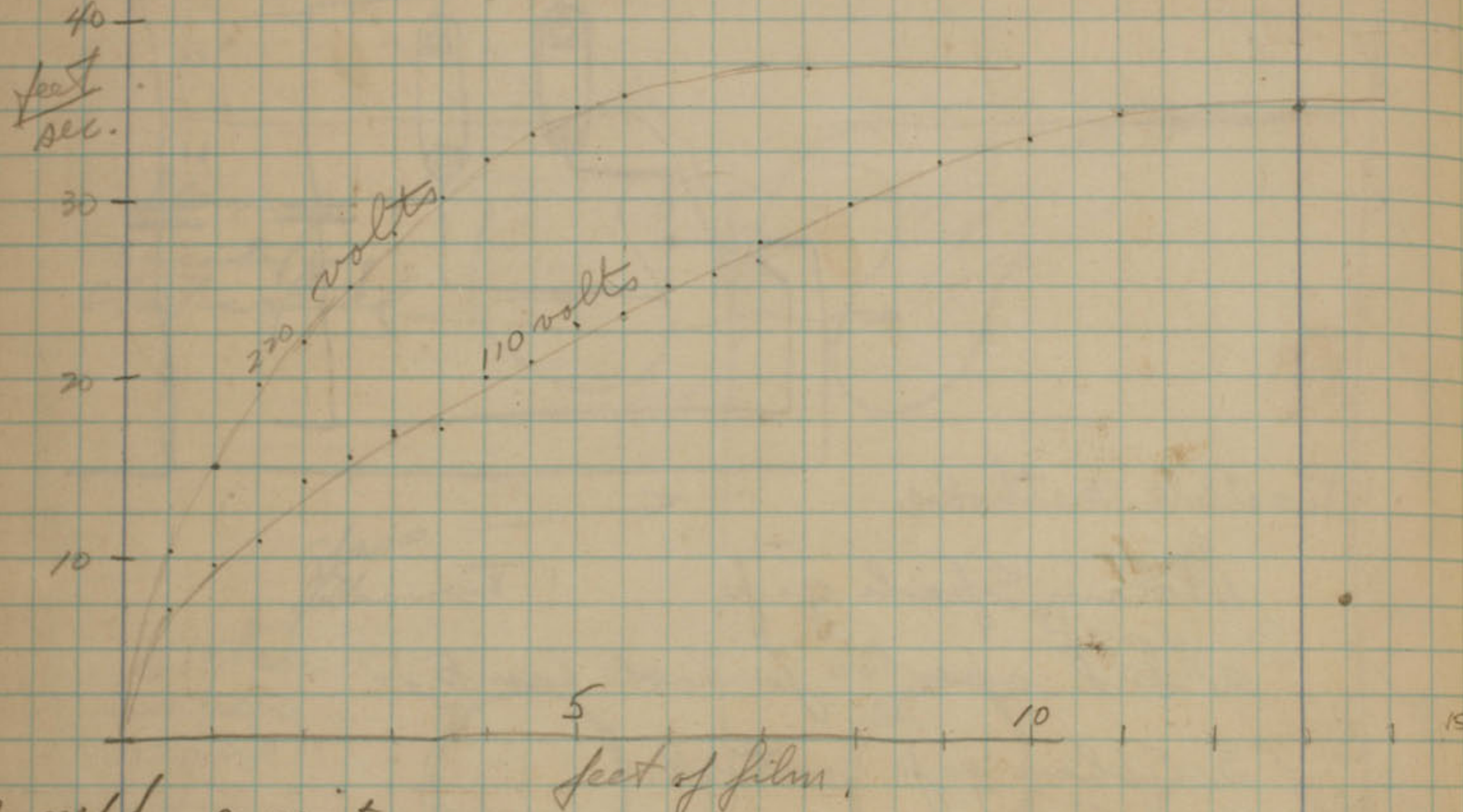


Possible methods.

1. Rotary Spark gap ×
2. Ind sparks for each lamp.
3. Sphere gap control.
4. Hg lamps.







13 mfd. capacity.

Acceleration curve of G.R. camera
Bodine Condenser motor 1725 RPM NCI 34
13 uf capacity. 1/8 h.p.

NaOH. Water.

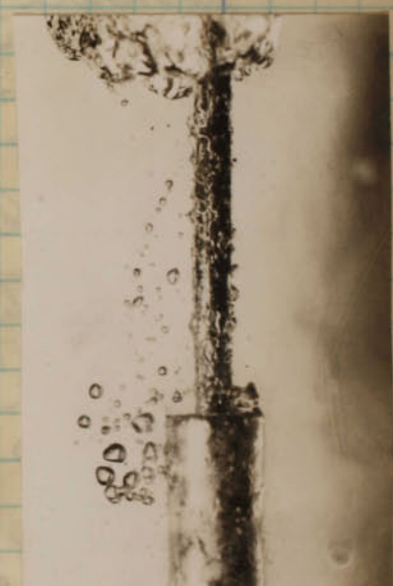
Oil

Oil

Brine

Brine

Brine



Water

Photographs showing Quenching.

July 13 1934
H. E. Edgerton

On Monday July 9 Germeshausen and I went to New Haven to take spark photographs of shot dropping in the shot tower of the Winchester Co. Left Cambridge about 7 am. and arrived in Mr. Edwin Pugsley's office at 11. Met Mr. Foisy and Phil Smith with whom we discussed the problem of photographing lead as it dropped from the tower in the process of forming shot. There was no 110 volt a.c. up there and so we could take no pictures.

We discussed a laboratory set up for photographing the formation of single shot pellets in the research laboratory where we could control the variables better. As a result of this conference we were to send some pyrex tubing one ft long with an inside diam. of 1½" from Cambridge. Smith designed a lead heater and a cup to fit on top of the pyrex tube, the cup to have a hole in the bottom for the lead to flow from.

On Tues and Wednesday the movie apparatus was put together and tested in Cambridge for the trip. The old 3 kw apparatus was used with either one or two 12" Hg mercury tubes.

Thursday we left my home in Watertown at 5:30 with the apparatus which we had packed in the car the night before. At 10 we were in New Haven and had started our setup in the room just south of Mr.

Notebook Number: T-4

Scanning and Separation Record

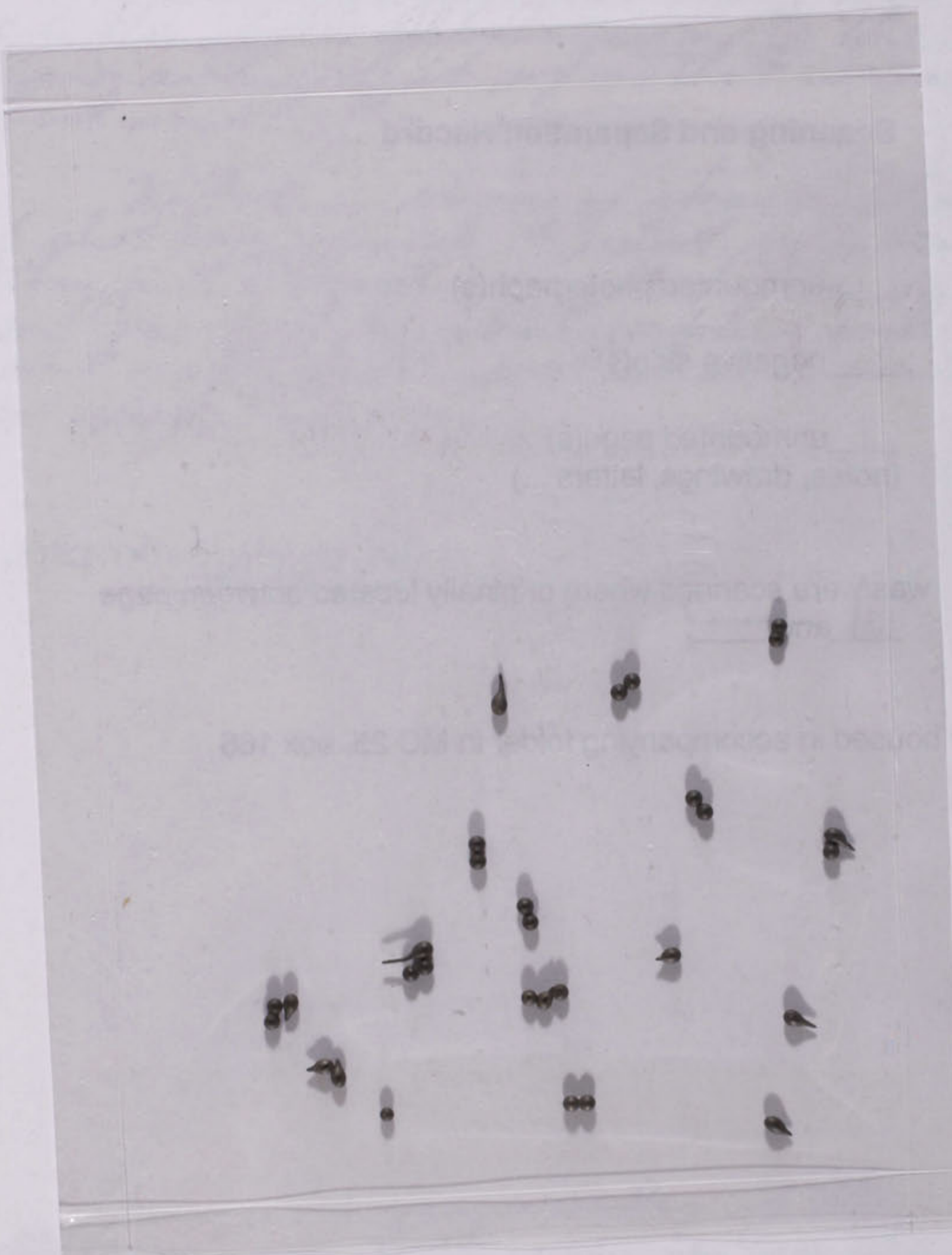
_____unmounted photograph(s)

_____negative strip(s)

1 unmounted page(s) encapsulated lead shot
(notes, drawings, letters ...)

was/were scanned where originally ~~located between page~~ in envelope on page
131 ~~and~~ _____.

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



Foisy's office. It was wired up by noon and nearly ready to go. Just before lunch we took the spark apparatus up to the shot tower and set it up so that we could shoot right after noon.

We took a series of spark photographs of shot being formed. #7 shot was being made. They put a small amount of tin in the pan for some of the photographs and it formed shot with tails such as are in the envelope below.

During the remainder of the afternoon we took movies of the formation of shot in the experimental set up in the laboratory. The pictures were taken as silhouettes at 600 per second.

The data sheet as used in yesterdays tests is on the next page.

Data sheet for experiments high speed movies of shot formation July 12 1934 in New Haven Conn at the Winchester plant.

{ H.E. Edgerton
K.J. Germeshausen
Phil Smith. }

N Haven. Conn. July 12 1934.

2500 11-28

DELIVER THIS COPY TO TELEGRAPH CLERK 1-A-2

PREPARED BY:
TELEPHONED TO
TO:
W. UNION
POSTAL
BY

TELEGRAPH CLERK'S COPY
OUTGOING TELEGRAM
DEPT. SYMBOL

1. Air 600 sec. Shadow. { 4% Antimony
96% Lead.

2 Air Lamp held over 600 Shadow

3. Air Ditto as 1 and 2.

4 Steam

5. "

6 tinned steel ~~bushing~~ tube
al Bushing.

7 Ditto

8. Ditto 6 7 but with Steam.

9 Repeat of 8. Higher head.

PREPAID
COLLECT
DATE:

REGULAR
D.L.
N.L.
DEF. C.
CLT
WLT

July 31 1934.
H.E. Edgerton

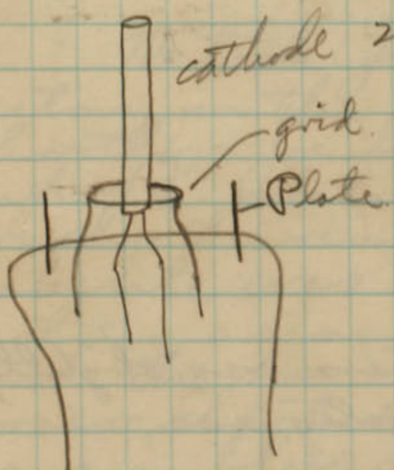
Returned yesterday from a trip to Aurora Nebraska to bring home my wife and children. Went out on train stopping 2 days at Chicago at the fair. This is a tough year for Nebraska, no crops or pasture. Drove 1628 miles in 4 days on return trip.

Dana Drury was here this aft., will return tomorrow morning to look at cars with the stroboscope.

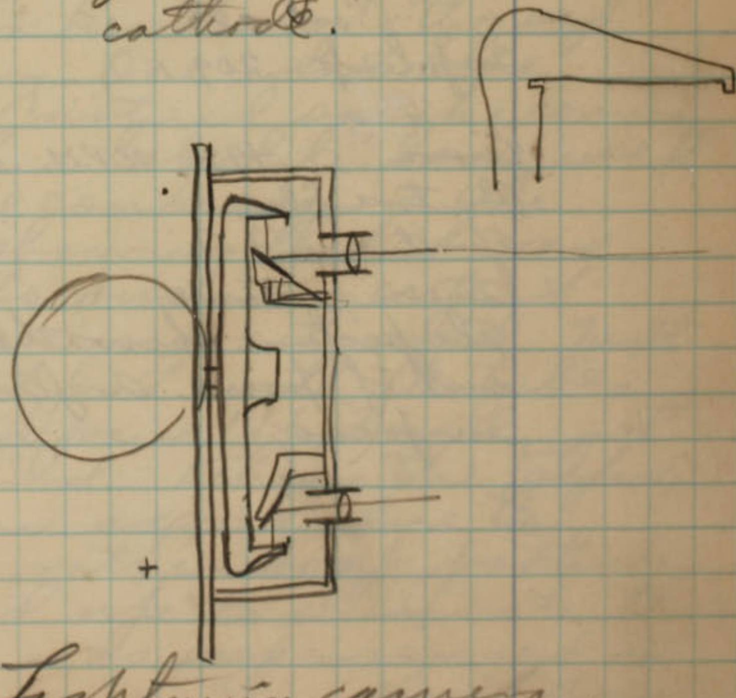
Made sketches of the spark (multiple 6) and camera for taking pictures at the Lever Bros Plant. Discussed with Pease the layout.

Aug. 2, 1934.

Arc-oscillator tubes.



also try uncoated cathode.



Lightning camera.

Aug 8 1934
H. E. Edgerton.

Over the weekend and the last few days we put the finishing touches on "6 banger" spark machine for taking photographs of the Rinso spray nozzles at Lever Bros.

The camera (Drum) and the spark apparatus was taken over to the Lever Bros. plant yesterday morning and was set up in the Rinso Development room. Some difficulty was experienced because of low voltage (102 volts) but this was fixed by the use of a variac autotransformer. Joe Graham ran the spray about 4 pm and we took a picture of it. The conditions are given below.

Film No 1.

Soap press 50 #
Steam " 54 #
Air temp in 435
" " out 285
Soap temp 209 F

Camera 4970 R.P.M.
Positive film
Aperature f 5.6
Camera verticle.
The picture shows that the camera was slightly out of focus. A few particles are in focus.

Aug 9, 1934.
~~S~~ Edgerton.

Report of work on Aug 8.

The motor on the high-speed drum camera was turned around on the base so that the wheel would go the opposite direction. Grier and H. Lawrence worked until 2 pm. on it. In the morning we made brushes and
No 2 assembled the camera. It was taken over to Lever Bros plant about noon.

They sprayed soap into the dryer with the man hole cover off so that as a result soap dust went over the camera and the spark apparatus.

No 3. The room got so hot that the thyratrons went off of their own accord. We stopped this by using 102 volts on the filaments.

Finally one of the kenotrons failed to charge up the capacitors and we could see a blue glow in it indicating gass.

Films shot.

Aug 9. work done.

No 4 We took four extra kenotrons to the soap factory in the morning. One went blue
No 5 shortly. Joe Graham noticed smoke coming out of a switch with a bakelite base used for short circuiting the condensers. The
No 6 bakelite was hot! showing that it was acting as a load to such an extent that the kenotrons were overloaded. Next
No 7 Grier shorted the output with the tubes on an blew another pair!!! Finally got straightened around. When the gaps
No 8 went off of their own accord due to dust particles or rather soap particles. The gaps were opened up to eliminate this
No 9. and then difficulty was experienced in making them fire regularly. About 4 pm. a condenser popped and we had to get a new one to replace it.

Also arranged to get some glass plates

to put over the spark reflectors to keep out the dust.

Aug 11, 1934
H. E. Edgerton

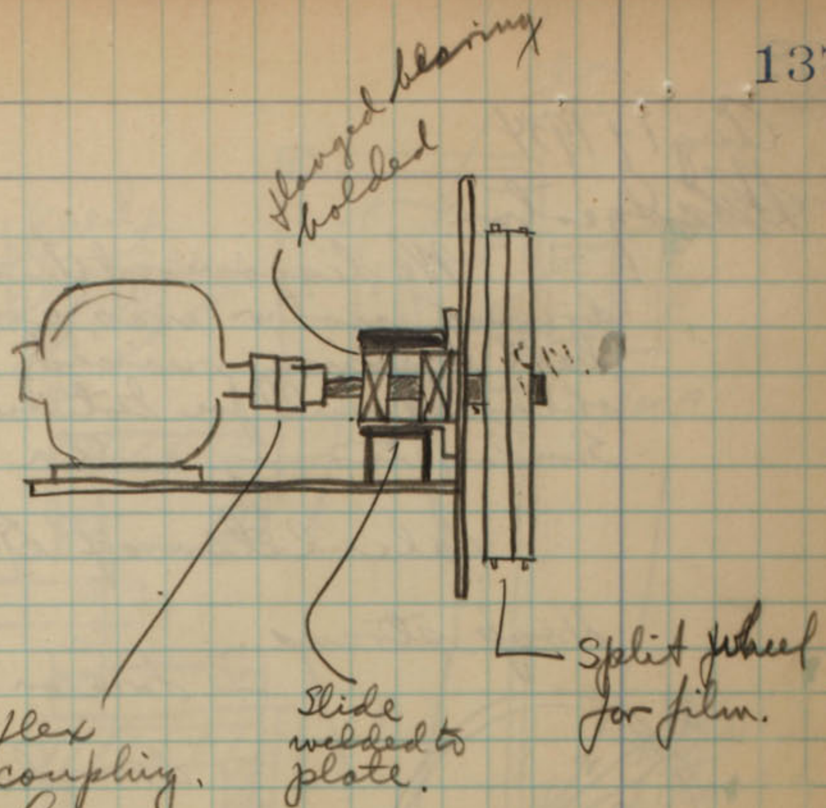
Report of work for Lever Bros Co.

The kenotron rectifiers ~~was~~ and circuit were modified in the evening of Aug 9 by inserting resistors to damp out oscillations due to gassy tubes. Also a high-voltage voltmeter was built using a Central Scientific Braun indicator for a moving element.

On ~~Saturday~~ Monday 13 ~~Thu 10~~ the outfit worked fine and Herb and I took several pictures especially at low speeds. The lens was set for about 3½ to 4 times reduction, f 16 using Agfa finegrain film. The development was with Rerat's fine grain developer so that 9x enlargements looked alright.

The new steel hy-tension film wheel was finished over the week end. On Sat 11 we decided to remodel the camera since during the week the shaft bent slightly and the wheel shook the framework at 5000 r.p.m. quite badly. Pease asked Scott of the Barbour Stockwell company to layout this new outfit and build it promptly the next week. Pease designed the arrangement for pulling out the wheel and cover but leaving the base and motor.

New design as shown a structure bolted to it so that it would run in a vertical position.

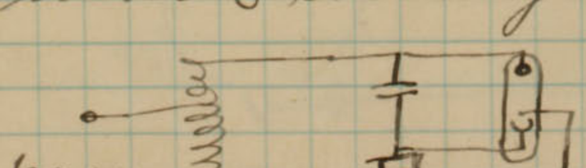


I took the film wheel to Lynn (G.E.) to get it balanced there through L.P. Shildneck. they had to build a shaft for it. and had to take off about one onze of wt on the edge?!

Received the new apparatus on Friday about 2:30 and took it to Teds. the bearings on the motor showed rough and one was bad.

Set up and took movies of a watch movement for Ingersoll-Waterbury on thurs and Fri evenings.

Discussed Strobotac circuits with Germeshausen today, especially a small 60 cycle one!! One circuit which looks good.



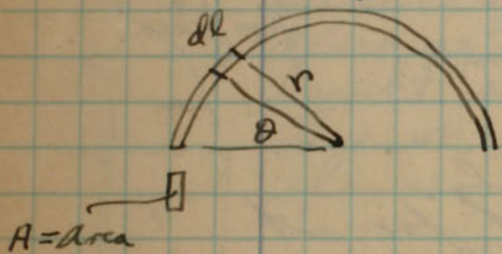
the neon tube is held off during the charging cycle by the small bias (drop across the rectifier) then the back voltage on the tube kicks it off suddenly as it flashed on the back wave. This circuit runs the strobo tube 60 cyc per second.

Aug 19 1934
HE Edgerton

We discovered that the end bell of the driving motor was cracked and the ball bearing ruined. A piece of stock was obtained and Joe Gotimer worked Sat and Sunday turning out a new end bell.

Calculation of Stress in wheel

Hoop stress.



Force on an element

$$dF = dm \frac{v^2}{r} \sin\theta.$$

$$dm = A\,dl\,\sigma \qquad \sigma = \text{density}.$$

$$dF = A\,dl\,\sigma \frac{v^2}{r} \sin\theta \qquad dl = d\theta\, r$$

$$= A \not{r} \sigma \frac{v^2}{\not{r}} \sin\theta\, d\theta.$$

$$\text{Total force} = \int_0^\pi dF = 2A\sigma v^2$$

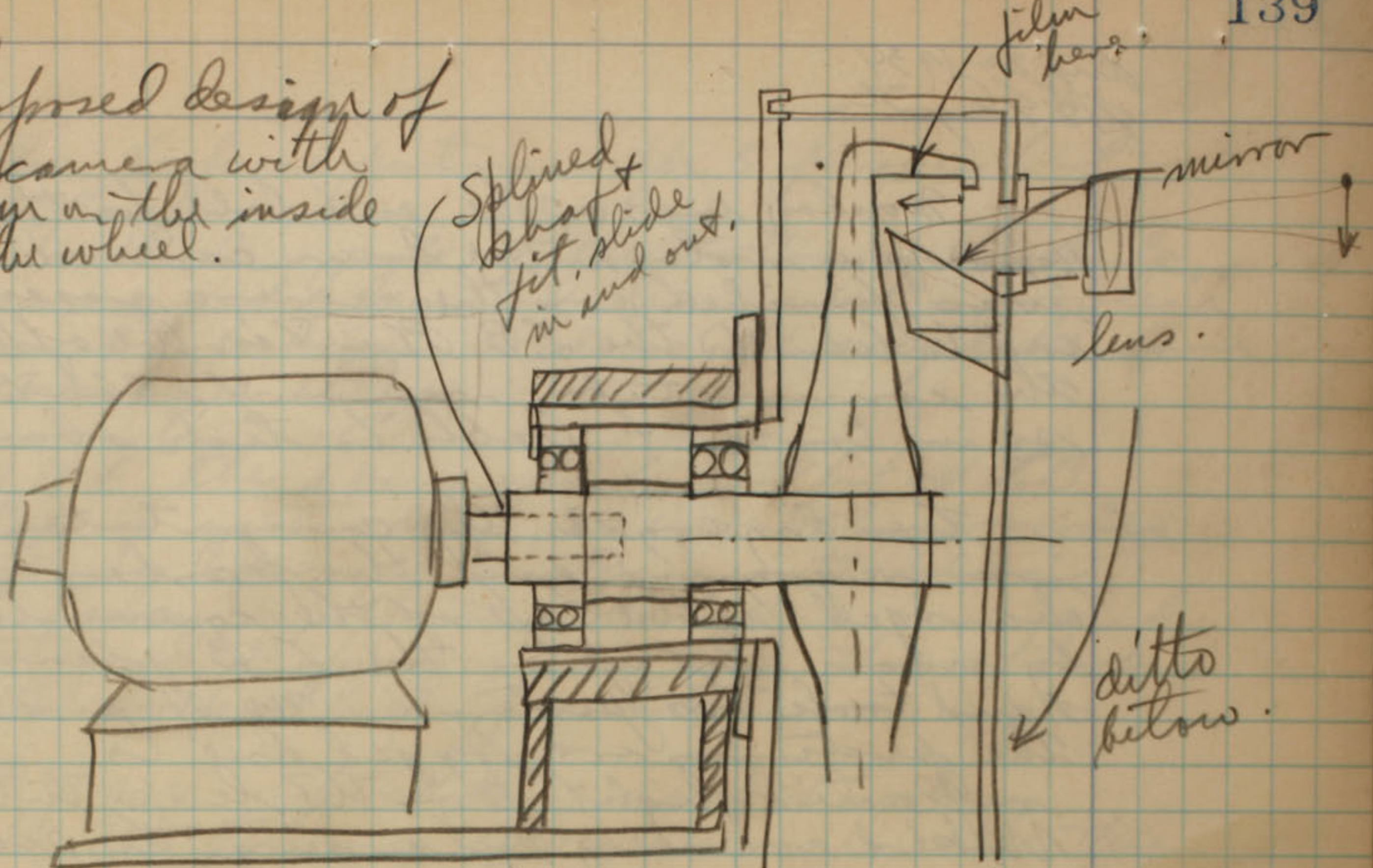
$$\text{Stress} = \sigma v^2$$

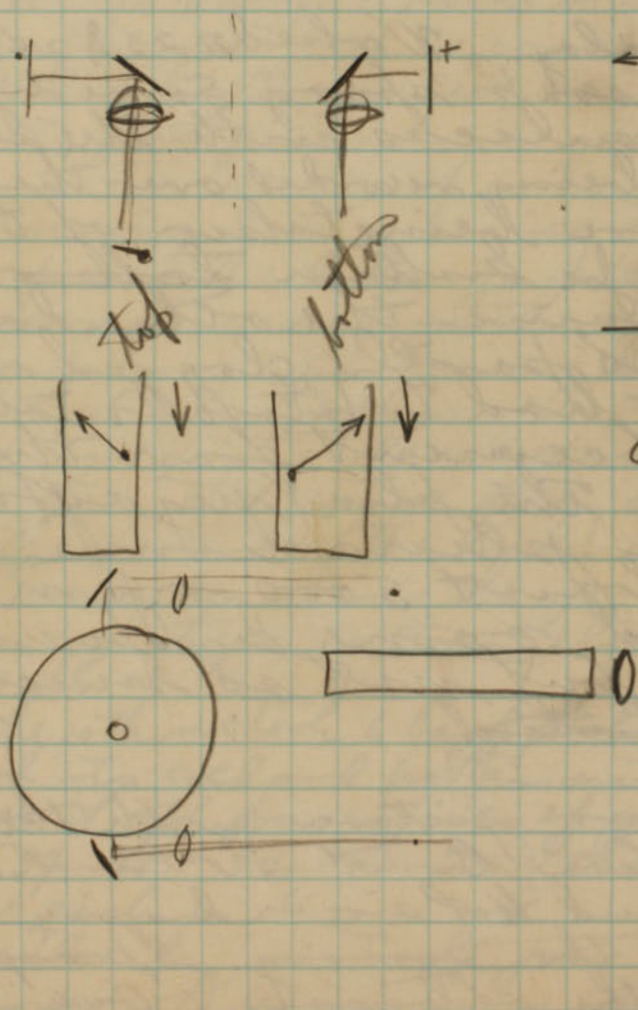
$$\sigma \text{ for steel} = \frac{480}{32} \text{ slugs}$$

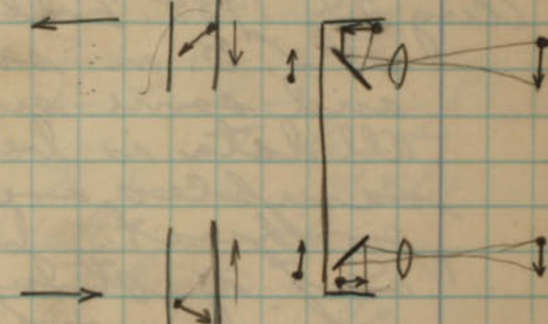
$$v = (10{,}000 \text{ r.p.m.})\ 500 \text{ ft/sec}$$

$$\text{Stress} = \frac{480}{32} \frac{(500)^2}{144} = 26\,000\ \#/\text{sq in.}$$

Proposed design of a camera with film on the inside of the wheel.







O.K. for Lightning photographs.

Aug 22 1934
H. E. Edgerton.

Monday Aug 20 the end bell for the 10,000 r.p.m. motor on the drum camera was finished and the camera assembled and taken to the L. B. Plant in the afternoon. The commutator ran out about .010" so we took it back to tech about 5 pm.

Tuesday Aug 21. The commutator was reground and the brushes changed to the top of the commutator by noon. Set up in the L. B plant about 3 and took two pictures no 21 and no 22. The pictures are fogged due to reflected light from the lens tube? Worked evening enlarging the picture.

Aug 24 1934 Friday. Worked 22 23 & 24 ~~total~~ at L. B. on soap spray. Some difficulties and some success with the arrangement. All data is being recorded over there and samples are being taken of the product. Joe Grattan ~~took~~ cleaned out a strainer the other day which was partly clogged up. Today we had to stop to take out a piece of cement from the nozzle. The film (neg agfa fine grain plenachrome) comes off at about 5000 r.p.m. We have had some difficulty from this but not so much as I anticipated.

Aug 27. 1934. Took more pictures with the 6 Barger at Lever Brothers Plant today. Used steam ~~and Hot air~~ in drying chamber in the morning. Sprayed into cold air in the afternoon. One of the glass insulators broke at ~~to~~ noon on one of the reflectors. It was replaced by another which also broke. Took one picture with 5 flashes but the flashes were irregular.

Van der Pyle of the Norton Co Worchester was over at 3 pm and discussed a problem about grinding wheels. We may take some movies for them.

Aug 29, 1934. The 6 Bang spark outfit at L.B. acted up yesterday. We were taking movies of Rinso sprayed by steam into cold air.

Today we repeated same in air, and photographed spray co nozzle in the afternoon with soap at high pressure.

Sept 7 1934. Spent Aug 30 and 31 working with P&G stock in spray co nozzle. Also this week on the same. Took some single flash photographs with three condenser banks paralleled together. Saw Mr Bodman yesterday and are to put pictures in report. Grier and I ran out a series of enlargements last night using 3 in a series to present the data from the 6 Bang pictures. Doing this gave us a greater selection of consequtive pictures because of misses overlaps and other difficulties in the outfit. We are also writing a longer report on the entire study of nozzle action.

Mr. Lenard of the Underwood Company was in to discuss the possibility of taking movies of type writers etc (on Sept 6.?)

Sept 12, 1934.

On the 10th we took 6 bang pictures of Super Suds sprayed into cold and hot air with the square pore nozzle. Also sent off four copies of pictures showing films 37 38 40 45 53 (three selected frames from each.)

Yesterday we took four shots with the 6 banger of Rinso in a regular Rinso nozzle into both hot and cold air.

Sept 22 1934
H. E. Edgerton.

I went to Chicago with Maxwell, Wiles, and Oxnard on Sunday Sept 16 on the 20th century. While in Chi I stayed at the Drake Hotel. We went over the high-speed motion picture with the attorneys.

Returned on Tues night arriving here in Cambridge on Wednesday night. I stopped off in Pittsfield and spent an hour with McEachron at the G.E. discussing lightning photographs.

Hamar was here today and he, Germeshausen and I went down to Mr. Rines' office to discuss my patents.

Sept 23. Cut Stearine neg.

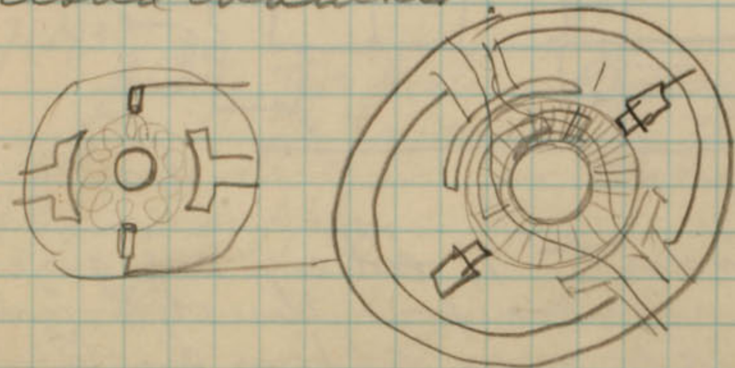
Sept 24. Registration at M.I.T.

Sept 25. Spark duration tests.

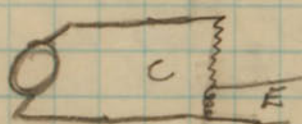
		R.P.M.	
Film	1.	4700	Reg. Spark opp. 4-12 mf cond in series. S.S. Pyranol.
	2.	4850	Dubilier Cornell ditto.

H E Edgerton
Oct 4, 1934.

Moved into new Laboratory on monday 4-111. Quite a job to get everything straightened up. Showed Street and Stevenson from Harvard mercury-lamps and sparks for lighting their cloud chamber.



D.C. Generators with no ripple ± 0.01%



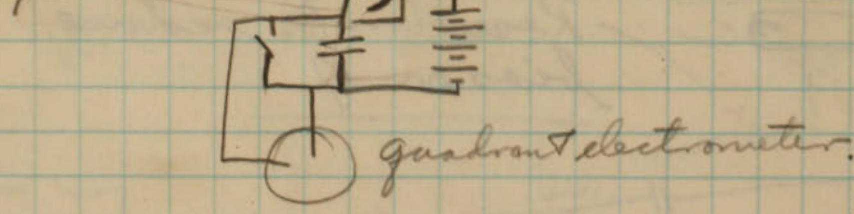
$$E = L\frac{di}{dt}.$$

$$e_c = \frac{1}{c}\int i\,dt$$

$$\frac{de_c}{dt} = \frac{i}{c}$$

Oct 10 1934

Method of measuring total light by photo cell for short flashes.



$$e = \frac{1}{c}\int_0^t i\,dt$$

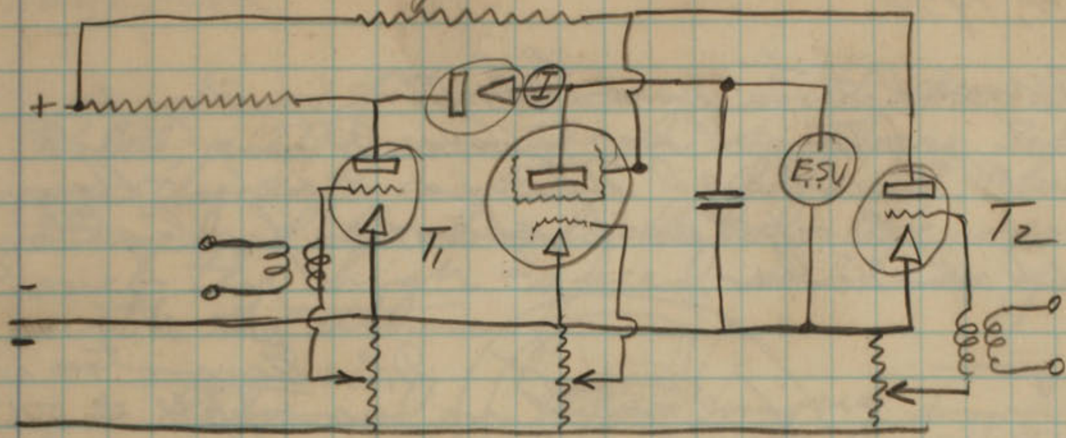
and since

$i = k$(light intensity)

then

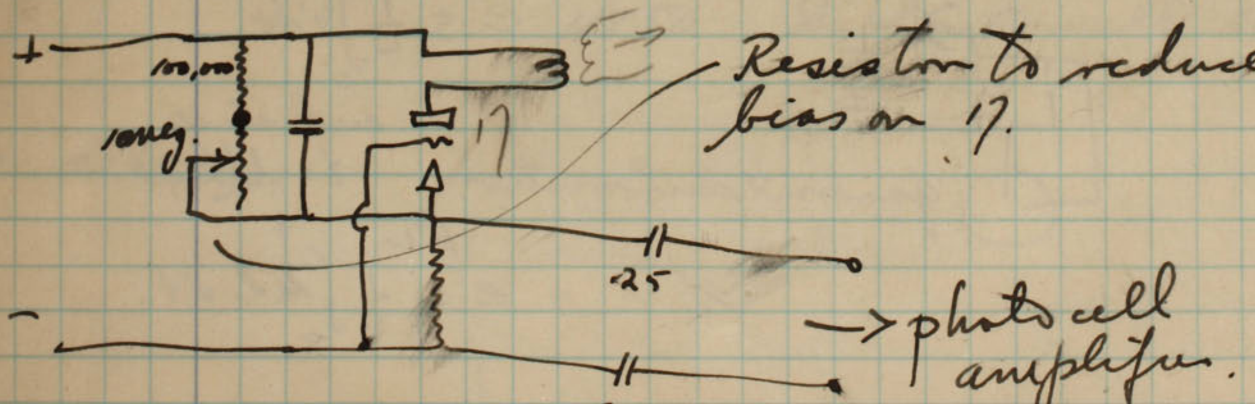
$$e = \frac{1}{c}\int_0^t k\,L\,dt.$$

Oct. 11, 1934. H E Edgerton. Circuit given to Holly.



Timing circuit T_1 when energized isolates the condenser from the charging circuit which is prevented from discharging by the rectifier tube through the thyratron. The screen grid tube acts as a current limiter allowing a constant current to flow from the condenser. The voltage drops linearly with time until the second thyratron T_2 trips, reducing the screen grid potential to stop the leaking current.

Oct 13 1934. Yesterday I worked with a photo cell trip for the spark machine. The circuit of the trip mechanism was modified as shown to reduce the bias and to therefore make it easier to trip the thyratron.



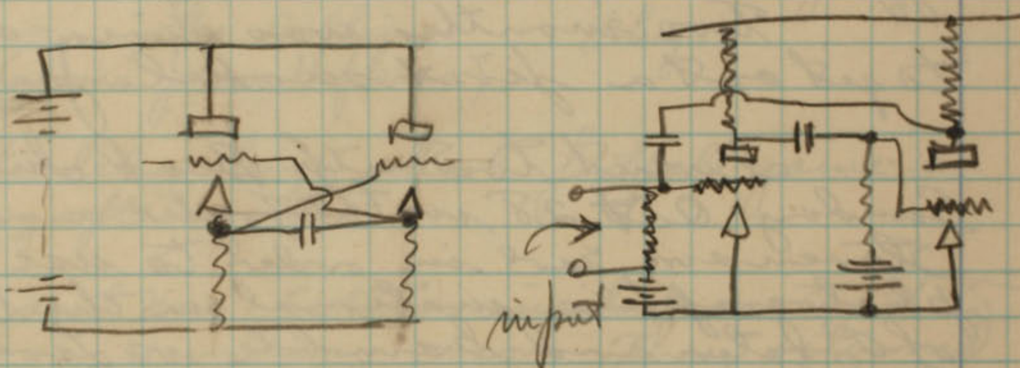
Oct 14 1934
HE Edgerton.

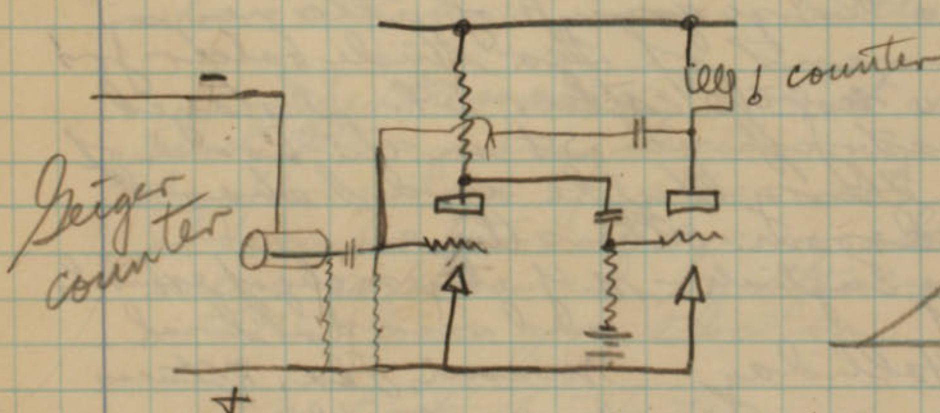
On Saturday I experimented further with the photo cell trip of the spark outfit. Took pictures of a golf ball splashing into a pail of water.
Height — 24 inches ± Verichrome film f 11.
3 uf 16000 volts.

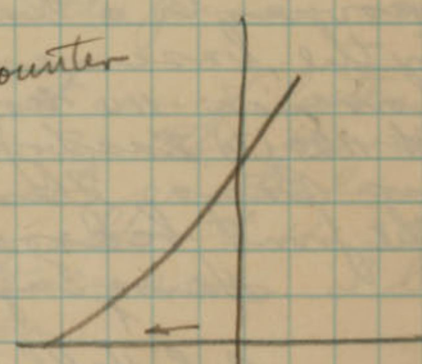
Oct 17. 1934.

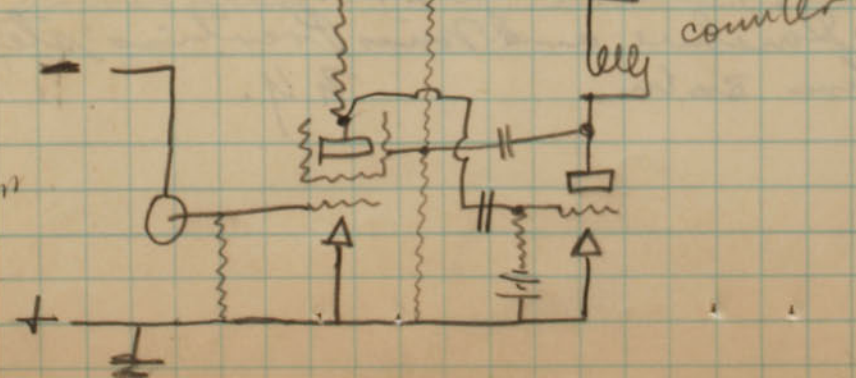
I took two broken Raytheon rectifier tubes out to the Lette company this afternoon and got one new one for test in our 30kw Power supply.

Regenerative circuit









Nov. 9, 1934
H. E. Edgerton.

On Friday Oct. 26 a conference was held at the General Radio co. those present

Mr. Eastham GR
" Burke GR
Wilkins GR.
Germeshausen
Edgerton.

Mr. Eastham was in favor of pushing the Strobotac but did not consider the 60 cycle stroboscope to be of any use because of possible small sale.

Two months was given as time to get out a first model. Jan 1.

I went to South Bend Ind. on Sunday Oct 28 with B. Fogler and Stevenson, Earl in order to use the photographic material in the trial of Procter and Gamble vs Lever Bros. On the evening of Oct 29 I showed the movies to a large group of attorneys in the basement of Geo. Studebaker Jr's home on 110 North Esther St. I stayed at 1120 (?) East Jefferson St in the home of Mr. Baus, Harry Wylde and I shared the front bedroom. Others there

Harry English - N.Y. atty in chg of exhibits and record at trial.
Bob Holliday Miami, Fla. Witness during trial.

Miss Donahue and Miss Prentiss sterogs.
Lever Boston. N.Y.

cont.

Wed ~~evening~~ afternoon Oct 31 I went to Chicago on the south shore limited. Stayed at the Stevens hotel room 2010 and went to the fair in late afternoon and evening.

Spent Thurs. at the Univ. of Chicago. Doan was in Comptons lab. I looked up some references in the library.

Returned to South Bend on the 7 o'clock train. I stayed in court until about 3:30 at which time I went out to Notre Dame meeting Northcott Elect. Eng.
Combs " " & phy.
Geo Collins Phy.
(from Johns Hopkins).

I attended a high-school football game on Saturday afternoon.

Mr. and Mrs. Collins invited me out to dinner on Sunday noon. They returned with me in the evening to Bass's house where we had music on the piano, radio, etc.

I spent Monday Nov 5 at court listening to Earl Stevenson's testimony. The movies showing the formation of stearine particles were shown on tues morning about 11:30 and were explained by Stevenson. I left on a 12:55 train for Boston.

Met at Huntington ave. station by Esther and Mary Louise. 11:20 a.m.