MC 241
Box 5 Folder 1

Radiation Laboratory, notebook, 1943-45

Massachusetts Institute of Technology

COMPUTATION BOOK

NAME	Number
W. B. Nottingham	1320

Course Notes and computations

Used from 1/29 1943, to 19 .

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F W Loomis

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

COMPUTATION BOOK

GENERAL INSTRUCTIONS

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

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

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

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

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

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

TECHNOLOGY STORE
HARVARD COOPERATIVE SOCIETY, Inc.
40 Massachusetts, Cambridge, Massachusetts

5	D T	Reading
30	P-7	Report reading.
50	D-T	conference notes.
80	D-T	Ideas and remarks.
130	P-7	Conference notes.
140	P-7	Ideas and remarks.

P-7 was the radar screen

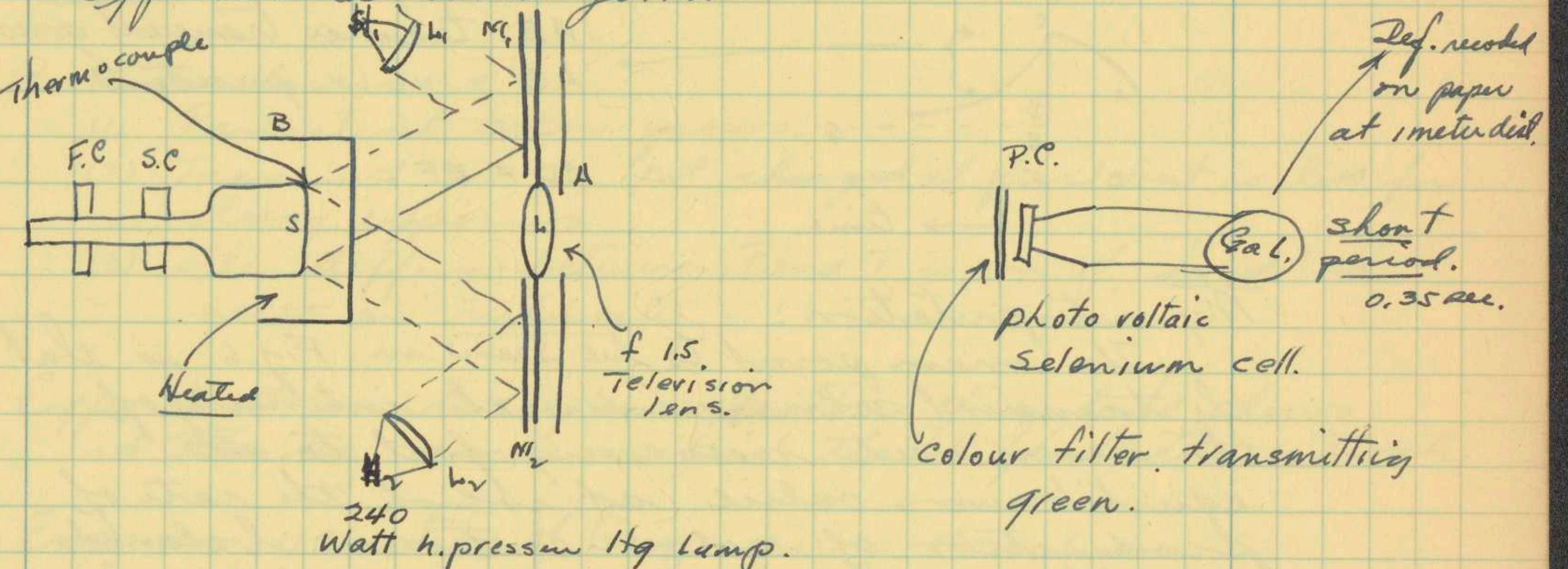
EN Sept '66

Notes on reading of D T Reports:

1/29/43 Report Filed as CVD 1210

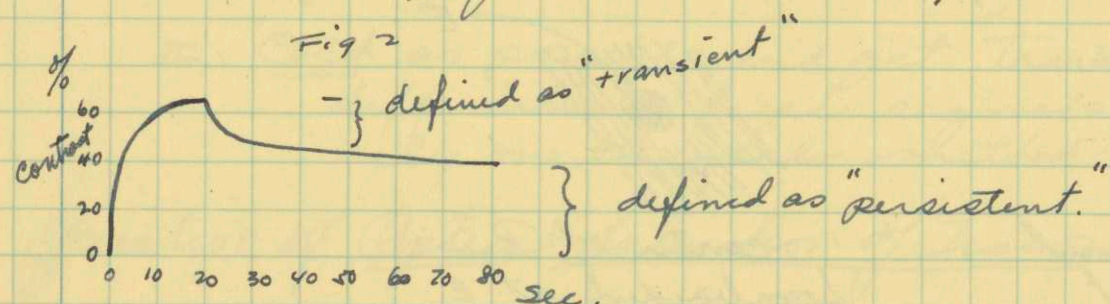
C.V.D
A S E E Bristol Report No. BR 172/42 4 Feb 1942
Experiments on the Colour Trace C R T.
Part I <u>The transient Decay</u>.

Experimental arrangement



Results in this report all for <u>8000 volts</u>.

Spot was un-focused and the beam put on by "key." and record of growth and decay taken.



Other curves are shown in report for which the Hg. Lamps were off part of the time.

Results are:

(1) Light does not effect "build up"

(2) No decay without light at a temp of 35°C.

Repeated application of beam.

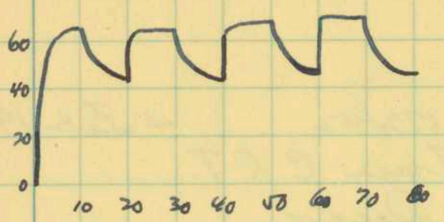
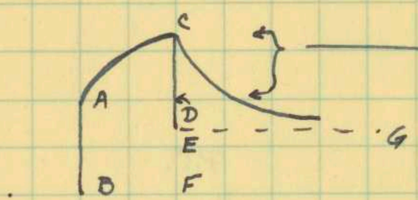


Fig 6

Brit. interpretation



AB taken as transient growth.
AC " " persistent "

CD = EF

My interpretation:
The main point to be seen in Fig 6 is that the transient color under the intensity of the beam used rises very fast to an equilibrium value at which the rate of production of color centers is balanced by the rate of removal which is thus shown to be influenced by electrons and light.

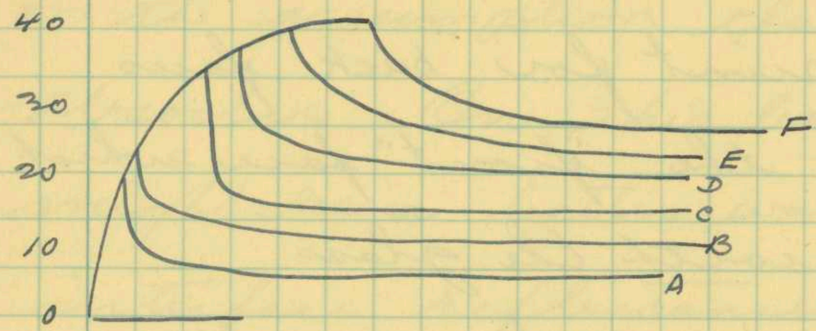
The next paragraph calls attention to the "halo" effect described as follows:—

area darkened by persistent color.

center of P is bombarded at E.
At the edge of E there seems to be a bleaching effect. Due to the stimulated decay of the persistent color as a result of weak electron bombardment.

Used for general clearing of tube by scanning.

Fig 9 shows.



A .5 sec. on
B 1 "
C 1.5 "
D 4 "
E 8 "
F 16 .
beam current 8 μa

Brit Conclusions.
(1) Persistent color grows.
(2) Transient " not changed at first but is less for long exposures.
(3) The differences between P and T is one of "kind" as well as "intensity".

Experiment on decay as a function of Hg light shows it ~~to~~ be more rapid the higher the intensity.

Exp on variation of temp gives conclusion.
(1) Range 35 to 50-60°C slight increase in trans. decay.
(2) " above 70°C also changes decay of P.

Claims logic of above leads to two methods of opeation.
I. Hot and use P trans only (130 to 160°C)
Objection is low contrast.

II Cold as possible and get "transient color to differentiate fresh signals from old and rely on the halo method -- for clearing screen."

Question of Optical Saturation of Traces.

The following statement is made:—
"When used as a transparency for projection traces of the same intensity as those employed episcopically are only faintly visible showing that the absorption of the transmitted light is small." (underlining mine)
"With reflected light -- the multiple reflections obtained from the black faces of the crystals make the absorption much more effective."

I do not know what is meant by "black faces". It seems to me that this is a misprint for "back" faces in contrast to the "front" face which is in contact with the glass.

An important experiment was made which I interpret in my own words as follows:

a KCl surface
~~Color~~ was produced on a plate of glass and taken out of the tube. The light back reflected from this was measured as 5.45 on the galvanometer with black paper very close to the film. Then with immersion oil to fill the gap the gal. read 0.9. Without paper or oil 5.30.

Summary

Film + paper	5.45
Film + oil + paper	.9
Film only	5.30

5.45 − .9 = 4.55 taken as interface surface reflection.

5.30 − 4.55 = 0.75 taken as light reflected elsewhere.

This division does not seem to me to be entirely satisfactory since the difference between 5.45 and 5.30 = 0.15 might have been the light reflected from the paper on the assumption that it is not a perfect absorber. On this basis then 5.3-.9 = 4.4 might be a better way to figure the interface reflectance. This is in agreement with my picture arrived at independently.

1/30/43

A statement is made on p 5 of report which at first was hard to understand. It corresponds to the situation as follows:-

The back reflected light is made up of two components Q_{35} + Q_{30} which have the proportion $\frac{Q_{35}+Q_{30}}{Q_{35}} = \frac{4.55 + .9}{4.55} = 1.2$ (according to their figures)

The Q_{35} are the only rays subject to absorption due to color centers.

For a contrast of 0.4 as observed we have

$$C_3 = \frac{Q_{35}' + Q_{30} - Q_{35} - Q_{30}}{Q_{35}' + Q_{30}} = \frac{Q_{35}' - Q_{35}}{Q_{35}' + Q_{30}} = .4$$

If Q_{30} were zero then

C_3 would have been $\frac{.4\times(Q_{35}'+Q_{30})}{Q_{35}'} = .4\times1.2 = .48$

The figure taken was 47% instead of 48% but the calculation must have been the same.

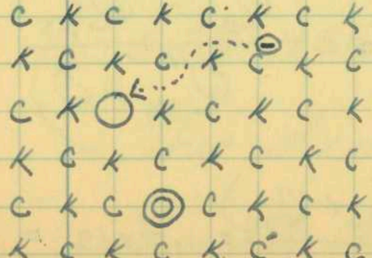
<u>A</u> <u>theory</u> of <u>the action</u> of <u>the tube</u>:

Refers to "Electronic Processes in Ionic Crystals" Mott and Gurney.

Coloration produced by
(1) Electron bombardment
(2) X rays.
(3) Excess alkali.
} all thought to be same effect.

Assumptions are
(1) <u>Missing</u> ~~a~~ <u>halide atoms</u> cause imperfections in crystal.
(2) An <u>equal</u> number of <u>Alkali</u> <u>atoms</u> <u>missing</u>
(3) <u>Electrons</u> <u>trap</u> at missing halide ~~sit~~ sites.
(4) A <u>trapped</u> <u>electron</u> is a <u>color center</u>.
(5) Absorption is due to electron transitions or "ionization". (Not clear here if it is uncertain which or if both are taking place)

Steps of excitation and decay are illustrated by the following.



Holes of two types are shown here.

(1) electron ⊖ is removed and it drifts to "O" site to form an "F" center.

this leaves a neutral Cl atom and a trapped election after the lattice has become rearranged to fit the new distribution of charge.

Heat, light or elections can re-excite the trapped election so that it can recombine with the neutral Cl.

My idea here is that the neutral Cl atom might change from atom to atom as a result of the heating and the transfer of an election from one Cl to another. Call the neutral atom an "N" center in contrast to the trapped election as an "F" center. Mobility of N centers could be ~~generated~~ accomplished by heating and perhaps by election bombardment but the fact that red light does not seem to effect the decay of "F" centers (which are accomplished by the return of the F center election to an N center) the mobility of the "N" centers is not increased by the "shorter" wave lengths of light. It is possible that very long wave infra red might mobilize the H centers.

The next paragraph speaks of the possibility that "The neutral halogen atoms - - . are capable of diffusing away from their anchorages in the crystal lattice". If these evaporate or combine with other Hs to form interstitial molecules of Cl_2 then the F electrons have no place to go and thus *persistent* color is produced until ~~the~~ a corresponding loss of alkali has been produced.

(This does not sound too good to me)

Beginning on page 6 and continuing is a "theory" of decay of "F" centers. The definitions of "α" and F(T) are not quite what is used because after defining these as they are they should be multiplied by a new constant "β" which is defined in terms of the number of recombination taking place per second for unit concentration of ionized F's and N's (the notation used is x and y) The equations could be ~~rea~~ rewritten to be a little more exact as regards definitions but the conclusions would probably not be altered. The step that seems to be incompletely explained is the relation between color center density and the galvanometer deflections as a function of the time. This should be examined

On p. 12 there is appendix II which serves to explain the relation between the galvanometer deflections and the ~~concentration~~ "number" of F centers present. The whole ~~ala~~ analysis is loose and should be reexamined.

2/1/43 Report filed as CVD 1461 24 April 1942

ASEE Bristol Report No BR 516/42
Experiments on the colour trace CRT.

Part II The persistent Colour.

July 16'43 About a month ago, Received a copy of a letter to Soller from Seitz dated June 15. Some of the main points:-

(1) Going to do exp with "additional agents" added to pure KCl.
(2.) F band explanation the usual one. Considers Molnar thesis supporting evidence. Omits "R" band from consideration but still believes in original exp. of R. Band.
(3) (a) F centers produced by trapped electron.
(b) Thinks electrons diffuse in other parts of crystal beyond region of primaries.

Sept 28'43 OSRD - London Mission SOL 7815

Diary of J. T. Soller

Visit to England Aug 14 - Sept 7.

Discusses various aspects of Cathode-ray-tube properties and production - Considerable details on Methods used for Skiatrons pages 14-15 and 16. Some points are as follows:—

Bulb. Cleaning:-

(1) Glass bulb placed in large bath of chromic acid for at least ½ hr and preferably over night.

(2) Tap water rinse

(3) 10% KOH solution for 20 min.

(4) Tap water rinse

(5) Distilled water rinse

(6) Dry in hot air.

Aquadag:-

(1) Aquadag is applied with a cotton swab. no binder being added.

(2) Dry in hot air.

(3) ~~Bake~~ Bake at 450°C for ½ hr.

Gun Cleaning:-

Less than 15 min before sealing in of gun (complete assembly excepting getters)

(1) Dip in boiling distilled H_2O and twirl around. This to get rid of chlorides etc due to handling.

(2) Dry in cylindrical oven 400°F

(3) Weld on getter.

(4) Seal in.

preparation of KCl:

(1) KCl ("Analar grade") put in Hysil tube evacuated and baked by flaming for 2 - 3 min at approx 400°C.

(2) Remove and grind to powder.

(3) Mix Al with powder.

(4) Put required amount in pellet press and form pellet

500 mg for 3½" tube (VCR - 520)
1250 " " 9 " " (VCR - 516)
(?)

(a) Note KCl after baking and forming into pellets is kept in dessicator (P_2O_5) at all times until put into evaporating cup and sealed into CRT.

(b) Method of melting KCl in glass formally used, was abandoned because it was felt that it introduced impurities.

Pumping and baking.

Room temp to 450°C in 20 min.
Hold 450 10 min
Drop to 200°C " 45 min.
Open and cool to room temp.
act. cathode → Evap. KCl take about 10 min.
Getter flashed
Seal off.

Vac. guage. =

Electron current 20 ma.
ion current 2 μa } Ratio 10,000
(My Estimate vac. as 10^{-5} mm Hg.) ✓
ion current 12 μa peak of evap.

Precautions:

(1) Keep KCl in pots
(2) Scrape pellets with razor blade.

GEC 8039

Visibility problems associated with the skiatron
R G Hopkinson Aug 4, 1942 (See page 44)

This reports covers experiments for the determination of the "just appreciable saturation difference steps" (S.D.U.) for the skiatron.

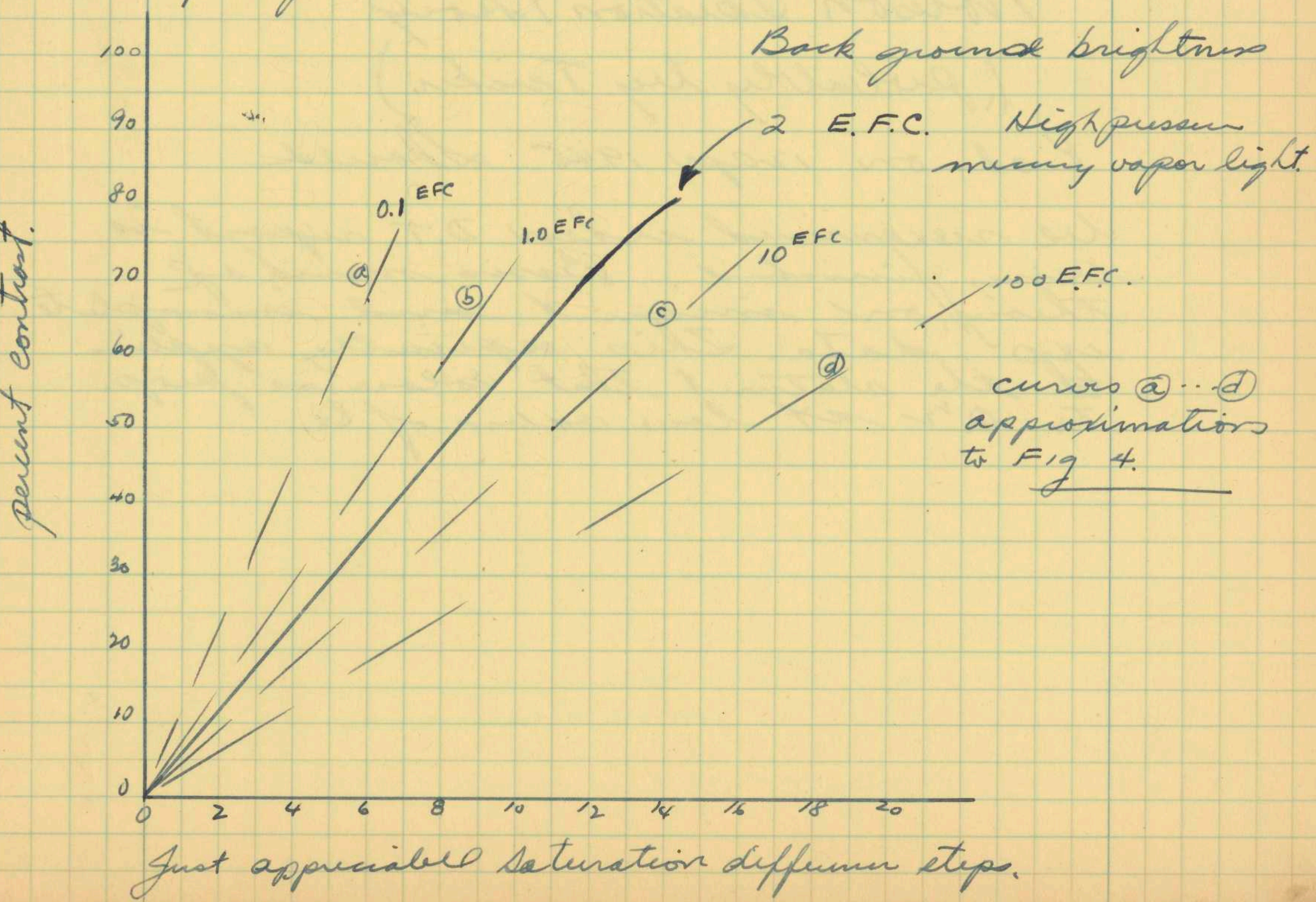
Wedges were prepared which were supposed to have the same absorption characteristic as KCl – No evidence to support this is given. Therefore the results apply strictly to that

percent contrast.

particular absorption band or set of bands in the wedges produced. If the color match is quite good then the results probably apply.

The conclusion was that for equal steps in contrast there are equal steps in "appreciable" discrimination.

Fig 9 gives:-



For pattern widths of about 1 mm the contrast steps are greater for discrimination.

ASEE 4468

Cent. radio - Bureau Ref. 45/1437
Also WR 1545

Adm. Sig. Est. Ext.
Wills Physics Lab.
Bristol.

28 Dec. 1945 - Report BR.S. 1575/44/XQ2.

Notes on Skiatron Theory
(probably by Tricker)

Read on 12 apr 1945. Should be reexamined when D.T. report is being finished. Basis much of theory on incorrect and incomplete exp. data. This especially applies to the statement that colour is prop. to $Q^{1/2}$ at low values of Q.

Brit. Report. May 26, 1943

EMI 2413 EMI 2413 (Electrical and Musical Indust. Lim.)

Report covers contract work 2/23/42 to 1/16/43.

Development of liquid settling

1A Settling methods.
Settles in water with small amounts of electrolytes.
Use zinc borate for binder to glass some times.
" CdS (no activator) same way.
" ZnS. CdS " " " "

1B - VCR 140
ZnS. CdS .4 gm. binder to glass.
Yellow layer. 5 gm ZnS. CdS. Cu (similar L. & West 0132A2M)
~~Sodium~~ Dry completely.
Sodium Silicate binder.
ZnS. Ag (sim. L. & W. 102A1)

Other details given.

1C - VCR-85
Two tubes described with different weights of blue.

1D - VCR-517

Methods again described.

Mention of water used here.-

Double distilled H_2O 350 ml.
NaOH .002N
$NaSO_4$ .01N

Mentions that in this tube "flash is not of great importance in comparison with brightness of the after glow" - -

2B Exp in demountable tubes

Studies of screen efficiency.

2C. Excitation eff. of yellow as a function of wave length - Details not given but I might assume that the max. is shorter than 4380 Å.

2D Mention is made of decay char. but no details.

TRE-2567 (1) The efficiency of production of light by Afterglow Phosphors. — Cent. Radio Bur. REF. 43.2191

TRE Memo. / BHM/1

Claims excitation by pulse light (Time and intensity not stated) gives after glow intensity approx prop. to square of blue intensity. (No details)

Total light also proportional to square.

Claims that storage of energy increases efficiency from low ~~of~~ value of 10%.

Low efficiency supposed to be due to "quenching". Considers this as indication that high "build up" factors may be explained.

(2) Exp with new decay curves.

Claims that new phosphors have been developed which have decay constant of 50 m sec. with exp decay (We could use it).

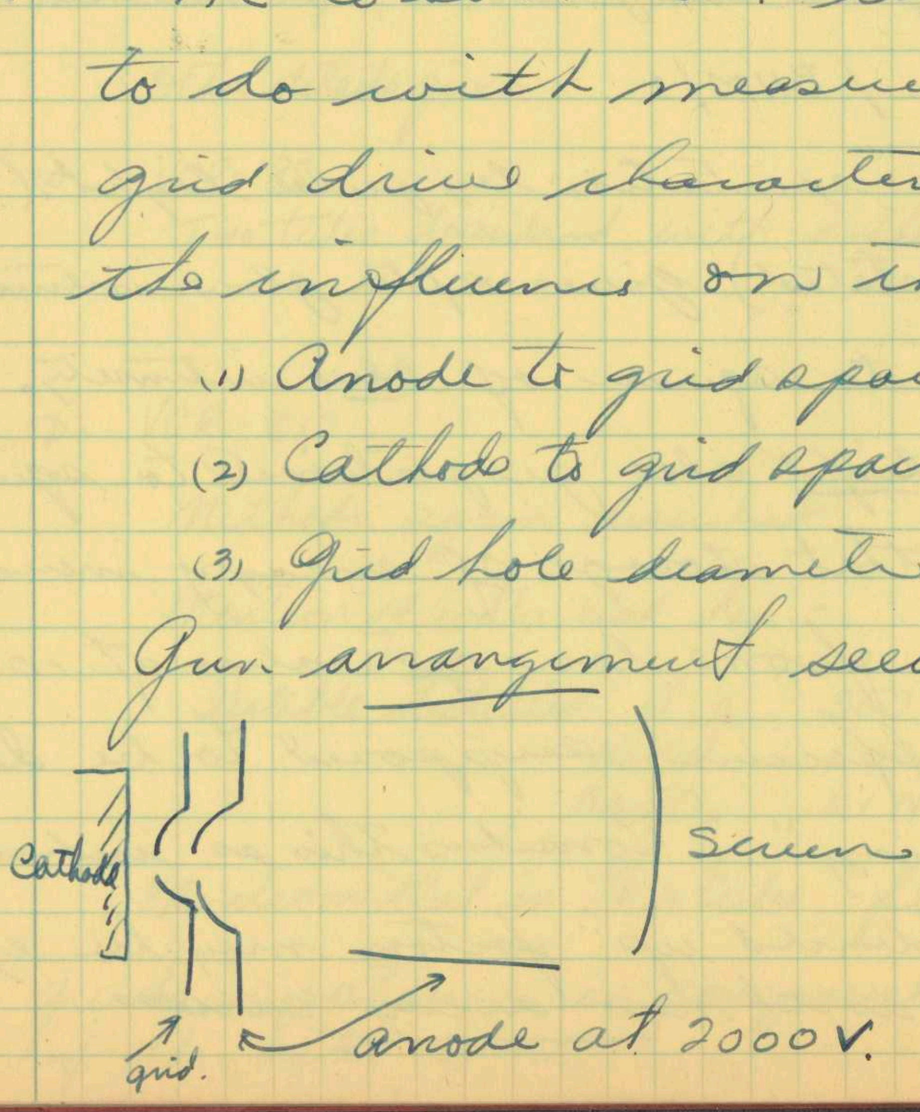
Should write for more information.

Aug 6 '43
COS 2586

There are three reports from Research Dept of AC Cossor. Ltd. which have to do with measurements of grid drive characteristics and the influence on these of

(1) Anode to grid spacing.
(2) Cathode to grid spacing.
(3) Grid hole diameter.

Gun arrangement seems to be



Analysis depends on "assumed" cut off and a log-log plot to determine the constants of Eqn. $i = AV^n$

V is the grid drive from "cut-off"
n comes out 3 to 4
k constant not named.

Numerical data are given and plots of $i^{1/3}$ should be made.
Further examination of these reports should be made.

Sept 24 '43

CCRTD - 2562

(Committee for Coordination of Cathode Ray Tube Development)

Read three reports giving minutes of meetings held

April 21	'43	CRB - 43/	2544
June 2	43	"	2927
July 14	43	"	3472

These meetings discuss many general problems of CRT developments. It is easy to see an influence of our work on their discussions when screen properties are being discussed.

On page 5 of 3472 is a quotation from Black's letter. Mostly correct but not in all details.

(This and others similar reports should be studied very carefully if I ever go to England).

<u>TRE Report</u> 1492 - Wilkins + Garlick.

(work completed before May 28 1943)

Discuss in some detail measurements made at Birmingham using apparatus which give much of the same information as we obtain A, C. D. & K. Screens are studied and most of the results are in close accord with ours as found in latest report on British tubes.

Feb 3 '44 Above report read again today.

20 line raster used with line width 1.5 mm (just touching) raster 3×3 cm². Sweep 10 kc and 500~.

<u>Spot velocity</u> ~~30×10~~ 30,000 cm/sec

time for spot diameter $\frac{.15}{3 \times 10^4} = 5 \times 10^{-6}$

The average diameter of a circle is $\frac{8}{3\pi} = 0.85$

$0.85 \times 5 = 4.25 \times 10^{-6}$ sec. - The spot is not a uniform circle but has more concentration in the centre and ∴ areas hit are excited about 5 µs and much of the area has negligible excitation.

Garlick + W. compute as puls length approx 3 µs: I <u>can not see this</u>!

Feb 3 1944

TRE
T 1550

G. Bradfield and Dr. G.E.J. Garlick —

Comparison of afterglow characteristics of CRT screens with and without cyclic excitation.

work done during Sept 1943

File number at R.L. TRE 3073

Washington number WR-992

"M" screens studied 4 KV. (Screen same as P.7)

Some points from summary

1.3 Build-up ratio considered unimportant when noise excitation exists.

1.4 "Cyclic-background" increases brightness increment due to signal. Optimum exists

1.5 With "Cyclic" excitation decay is slower.

1.6 "The intrinsic efficiency of any particular screen for visual presentation of radar signals (may) be established quantitatively --"

Tubes tested :-
"VCR 521 termed VCR 138 N. 3378 with M screen"
and CRT-9QDEM2

TRE
T 1492

continued from p 35

Beam current said to be about 70 μamp.

and Q = 10 mμc. for one raster

compute $\frac{70}{9} 10^{-6} \times 2\times 10^{-3} = 15.6$ mμc.

45 μamp gives an average Q of 10 mμc.

1 to 10 rasters gives control of Q and decrease in raster area increases Q beyond this, and decrease in current decreases Q.

Experimental range used seems to be 1 to 1000 mμc.
Pulse ammeter seems to have been used for current measurement.

931 and Wratten 15 used.

Brightness standard from opal glass.

Scales in e.f.c. (effective foot candles)

Integrated flash on $\frac{1}{10}$ second integration (no explanation)

Practically all conclusions and general results in qualitative agreement with ours.

TRE T1550 Continued

2.4 Refers to T-1492 and states excitation time is 8μs.

Raster series range 1 to 10 at 500 per second.

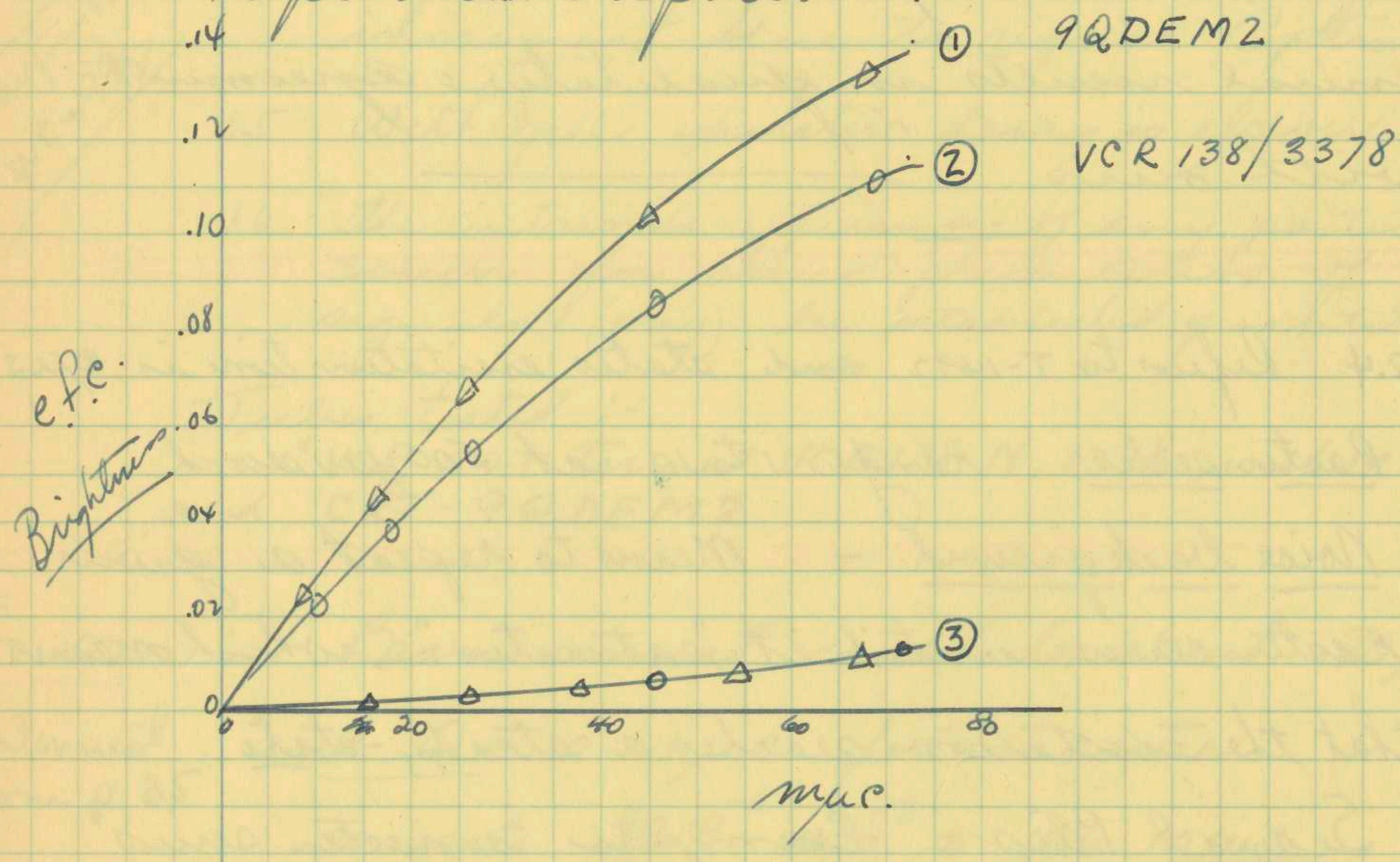
Noise background - Means to repeat a given raster series until it "saturates." which means to me that the excitation reaches a steady-state.

Signal Blip - Example a raster series of 2 might be used to create the "noise" then a sudden change to Series (Ser = 8) would constitute a signal blip which would perhaps be repeated 5 or 6 times.

3.1 <u>One second decay characteristics.</u>

3.1.1 In this section the term "excited cyclically once per second" is introduced. This seems to be the steady state brightness arrived at after an indeterminate number of one second repititions.

Fig 1 shows some curves ① ② ③ roughly reproduced as follows.



Curves ① + ② are for "cyclic" excitation
③ Deactivated.

I have to assume that ③ is the equivalent to Ck, or B, and ① and ② are

B_∞ or cb_∞.

Point is made of the fact that both tubes give the same results ~~at~~ as shown on ③ but differ on ① and ②. This is an accident of selection and may be interpreted to indicate ① has higher build-up than ② and both start at the same cb_1. Other tubes might have had the same cb_∞ and different cb_1.

Other measurements are made by establishing cb_∞ at Q = 7 ; 28 and 49 and then superimposing a ("blip") a single raster series of Q = 70 and measuring the total brightness one second after the "blip". Results are also shown in Fig 1.

3.2 Decay of the afterglow.

~~The~~ "Two point" decay curves are shown in fig. 2. Observation seem to have been made at 0.25 second and 1 sec. and slopes of straight lines joining these two points are use to determin

the "n" value. (Log B vs log t plotted)
Q = 70 μμc. olay value used.

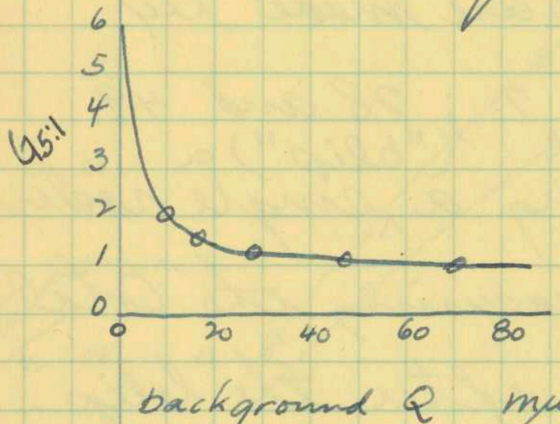
	n
"Cyclic"	0.5
Deactivated	0.83

Other conditions between.

Points out that lowering voltage increase "n" and intends to study effect.

3.3 Variation of $q_{5:1}$

Shows following in Fig 3.



Observes $q_{5:1}$ from deactivated screen as 6. with Q = 70. Puts on Q = 7, 14, 28, 49, and 70 by continued hitting and then puts on 5 blips at Q = 70. Nature of build up is as would be expected.

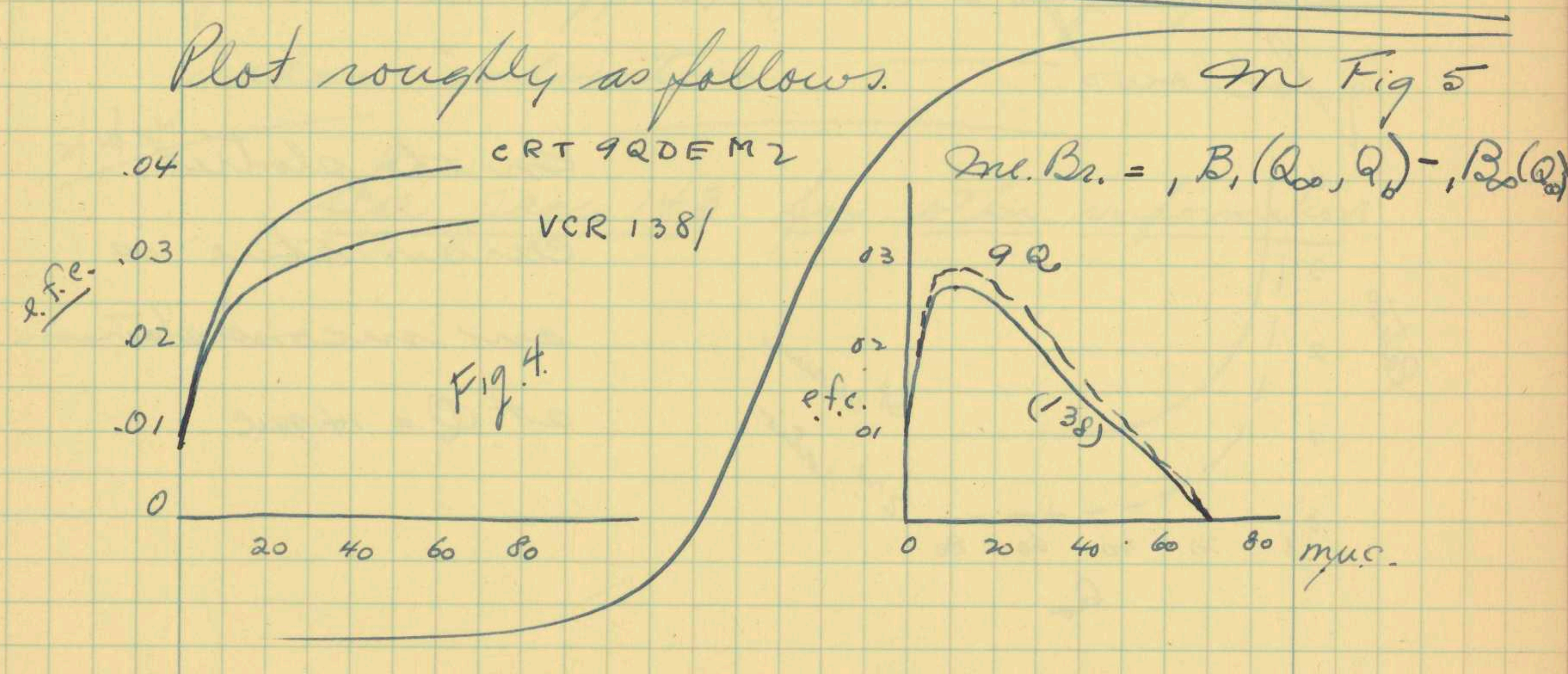
4 Interpretation of results.

4.1 Derivation of Sig. Noise Brightness Relations

It seems as though the following results are represented by Fig 4: The tube is pulsed at $Q = 7, 14, 28, 49$ and 70 and then after steady state allowed to decay for 2 sec. and the brightness measured. Call this ${}_2B_\infty(Q_\infty)$. The tube is pulsed to steady state and then $Q = 70$ is put on once and ${}_1B_1(Q_\infty, Q_b)$ measured at 1 second.

"<u>Incremental brightness</u>" $= {}_1B_1(Q_\infty, Q_b) - {}_2B_\infty(Q_\infty)$

Plot roughly as follows. In Fig 5



In this section two new ratios are defined these are in symbols (which are mine) as above :→

Brightness ratio /

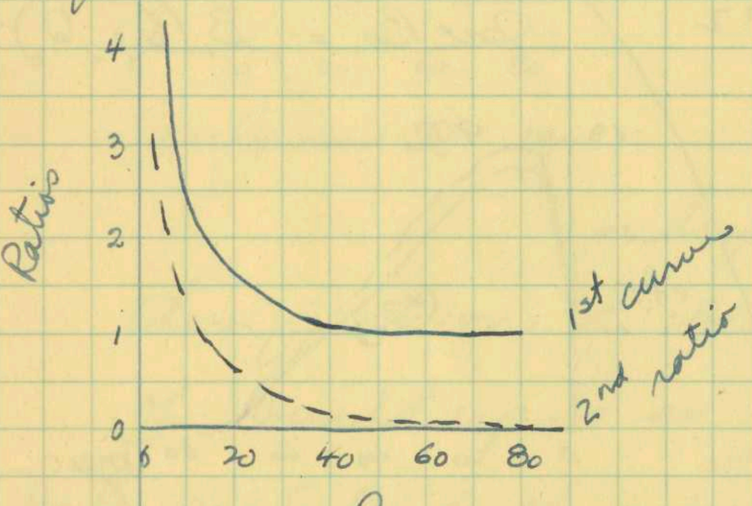
$$\frac{{}_{,}B_{,}(Q_\infty\, Q_b)}{{}_{,}B_\infty(Q_\infty)} = 1^{st} \text{ ratio}$$

Contrast ratio

$$\frac{{}_{,}B_{,}(Q_\infty, Q_b) - {}_{,}B_\infty(Q_\infty)}{{}_{,}B_\infty(Q_\infty)} = 2^{nd} \text{ ratio}$$

$$(1^{st} \text{ ratio}) - 1 = 2^{nd} \text{ ratio}$$

Curves for CRT 9QDEM2 are about as follows:



In the plotted curves there is an inconsistance at Q = 14 mc.

Conclusions:

(1) With cyclic background the build up ratio due to signal is unimportant.

(2) Cyclic back ground can increase brightness increment due to a signal by a factor of several times. There is an optimum.

(3) Index "n" is smaller for cyclic excitation

(4) Meas. using cyclic ~~back ground~~ excitation - - - should provide data on capability of a screen type to produce ~~#~~ definite radar indication.

2/4/44

See page 143 for other information

Justy brought over a number of reports and sent others. These were

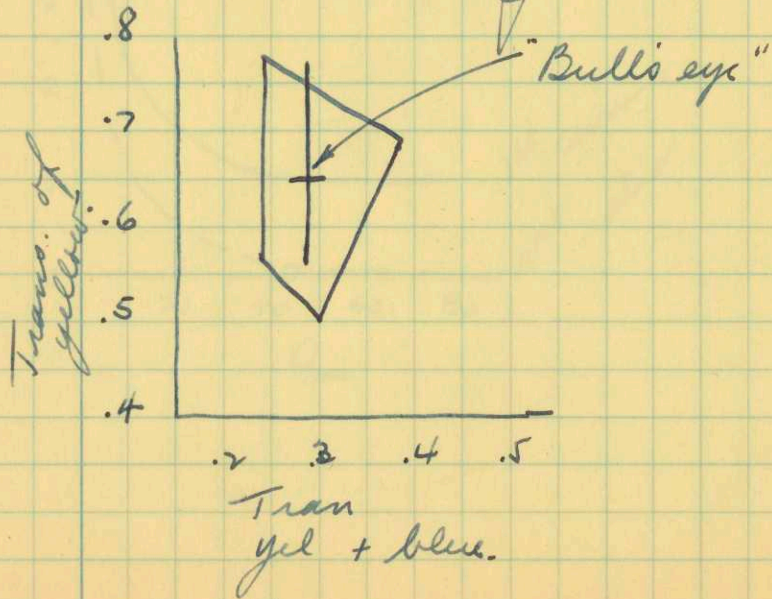
7889	Jan 9	'42	Hopkinson, Justy + McKeag.	
8039	Aug 4	42	Hopkinson	(Skiatron) (See page 18)
8259	Sept 7	43	Jacob.	
8261 (Dup.)	Sept 8	43	Hopkinson	
Spec.	Sept 22	43	Hopkinson	
Abs 8264	Sept 29	43	Justy.	
Notes	Oct 5	43	—	
8262 (Dup)	Oct 19	43	Justy	
8260	Oct 29	43	Jacob.	

G.E.C.
7889

Improved Screens for VCR 85 C R Tubes. (Ref. 7879)

This is a report on a change in phosphor which was composed of smaller grain material. Mean size 8 μ. - Result increased brightness and decreased graininess.

Discusses the establishment of the boundaries of the "target" diagram



page 18)

G.E.C.
8259

7/15/44

C.R.T. Equipment for measuring afterglow.
Sept 7, 1943
J. E. B. Jacob.

May 28 '43

Yesterday a conference was held in my office. Present were: Haworth, Soller, Bentley, Starr, Kelly, White, Guy and C. Discussed reorganization which puts Kelly, Hull (?) and Bentley in group, reporting to Haworth, with tube operation, operational tests and tube selection by operational methods as their primary function. Our primary function in D.T. is to develop new methods of processing, use of new materials in tubes, research in fundamentals, raster tests and investigation of new methods of test.

I made a point of the fact that the raster test system in 24-007 should be under our "control" just as the "operating systems" now in 24-033 should be under Kelly's control. In case Kelly wants tests made on our system we shall be glad to do them for him or cooperate with him in the doing of these. We do not want ~~it~~ the situation to arise which would cause disagreements because Kelly might consider that he had a "vested interest" in the raster system. In return we should expect to obtain the cooperation of Kelly's group to have operation tests made but we would not expect to use his system except with his full cooperation and under such circumstances that it would not interfere with ~~the~~ his program. I am not certain that Kelly agrees with this division but this is the only division that seems to me to be consistent with effecient operation of our equipment for tube research and development. Change over to take place on June 1st. Our group to be

White, Ivy, Windsor, W.B., Coffin, Lou

Mr Cherry, Mr Crampton.

June 1. Plans:-

Allyson pulse ammeter + power.

June 24 Gordon here today and yesterday Brought 10 tubes which were tested first by Kelly and later (today) by us. Yesterday a difficulty arose over the operation of our test equipment. Kelly objected violently to our plans to measure the 9E tubes. After discussing the matter with Haworth the plan outlined above on May 28 was agreed upon.

The tubes measured could not give more than a Q of 1. Measurements.

were made as near this as possible. Further study is necessary to establish the law of extrapolation. The ½ power law is now being used.

Had conference on June 22 to discuss the mechanism of D.T. with White, Swing & Windsor.

Dec 30, 1943 At Spraycliff. Obs. for tests yesterday and today. Observations up to 10:30 PM of no value because of open circuits in tube sockets and in connecting am. phenol. on tube mount. After that tubes were tested in following order.

12/29/43 10:35	DM 5113	- R.88	10:51 PM
11:00	5109		11:30 PM
11:30	5111	- R86	12:00
12/30/43 8:00	"	"	8:30
8:30	RCA - V12 -		9:25
9:30	RCA - PM116 -		10:10
10:15	DM 5112 -		10:30
10:35	GE 2970	- R79	11:00
11:10	" 2905		11:35
11:40	GE 2834		12:00
12:05 PM	2832		12:30
1:00	2859		1:15
	2846		

Observed some flying operations at night. About 2:05 AM Engine trouble caused crash in water off Block Island with loss of plane and man. Operations were all devoted to search today.

Summary of results.

Tube No	Rad No	Gun	I / Io Bias	Cut off.	I / Io at. 0.	T_1	T_1/P_1	Focus	Contrast	Decay	Block Island	Plomos.	General.
2832							6		max d. Satis.	Slow	15+		Back reflection seems to be low.
2834							37	Satis	max drive good.	Slow			Slow decay makes up for contrast.
2846								~~Good~~.	max d. Good	Slow.	15+	10	Left in system.
2859								Satis.	max d. Satis.	Slow			
2905		LA	.4	36	600	25	9						
2970		L.A	.4	36	560	24	9	Good.	Good.	Fast.	B 15		High drive ~~sta~~ signals last 15 sec. Low drive 4 or 5 sec. More uniform white of scan obs. but not bad.
U-12		L. A	.3	48.5	860	26	8	Good.	Good.	Med	A 15 B 15+	High Drive 15	Shift to 80 mi. satisfactory. High current gave high contrast.
PN-116		NL	.3	20	200	24	14	Poorer	Low	Fast		5	Plane at 35 mi. lost 5 sec. on D-7 - same sig. lasted 15 seconds.
5109	R-87	NL	.3	21	260	27	11	Fair to Good.	Good.	Med.	15+		
5111	R-86	LA	0.2	19	200	28	40	Good.	Good.	Slower	A 15 B longer.		
5112	R-90	LA	.4	14.5	130	26	14	Fair	Fair	Fast.	A - 4 sec B-15	3-5	
5113	R-88	LA	~~0.4~~ .2	~~21~~ 18.3	~~155~~ 215	~~26~~ 27	~~10~~ 13	Fair	Fair	Fast	15		
2860	GE Selection	90 mil LA		42		24 to 37%	6.3	This tube selected at Bridgeport for good operation on their SK.					

2/23/44

Discussed with Kelly some of his points having to do with specifications. He wanted me to "know" how he stood on certain points.

1.) Wants min "Q" of 1 contrast of 18%
2.) Wants 45 volt drive from spot cut-off.
3.) Wants min contrast at 45 v or zero bias of 30%
4.) Wants no spec. on preaging
5.) Wants no spec on decay ratio.

I advocated

(1) 22% min at Q = 1
(2) Drive from operating point and measurement of contrast or current. The measurement of contrast at this high drive only assures suitable proportion of electrons in gun.
(3) Set drive min in darkening of min gun and 22% screen.
(4) I want at least 1 mil coulomb /cm² aging

(5) Want control on decay-ratio at most suitable value after defined pre-age or else two classifications of "slow" and "fast."

Kelly went off sore because I questioned him on what he meant by the phrase "vidio-drive of 45 volts from spot cut-off." I did not see what spot cut-off had to do with vidio-drive.

---

jiny

May 20, 1944

Have spent considerable time with White, Ivey ~~Windsor~~ and Mackinly discussing the results of their observations and experiments of past 2 months. Have been thinking and discussing many features of theory in which I consider the trapping of the electron "holes" as very important. Details to be written up in two reports.

One of the conclusions of these consideration is that an excess of "metal" in the screen is desired. The more metal there is and the more widely it is dispersed the faster the decay. In order to keep the metal well dispersed ~~it~~ I thought that thorium should be tried and intended to do the experiment at Cenema Tel. with some thorium powder obtained at G.E.C. Owing to early leaving exp. not done but has been done here. See results of tube #158 Observations made show that the thorium reacted with the KCl to liberate some free potassium which went to the screen and resulted in "additive" coloring giving an effective contrast of about 30%. Tube #158 had a higher concentration of Th and it changed in reflectance enough to correspond to an additive contrast of 75% Tubes with Th had high initial contrast and very fast decay. Consideration of the "heats of formation" of chlorides serves as a guide as to the effectiveness of the reaction. It seems that effective elements react to produce chlorides which evap. over along with KCl and potassium metal but at the low temp of the screen a reverse reaction takes place in the light and the $ThCl_4$ is reduced with the absorption of the potassium by the Cl.

(May 20) continued.

Spent afternoon of May 18 at Fishers island testing tubes on proj. system. Others there were Soller, Bentley, Kelly, Lyman, Hartley and Woodland.

Bath tube system in poor focus and vertical system (Old R.L. unit) used for most test. Very clear to me that range of contrast expected from tubes as now operated is so far too much that application is rather sure to fail unless steps are taken at once to reduce the range to appox 10% to 20% as total useful range. That is no ~~stro~~ signal should be strong enough to produce more than about 20% contrast. Have made quite a point of this with Soller but as of today have not made much progress. Associated with this recomendation is the further ~~need~~ of the ~~best~~ following:—

(1) best possible optical focus.
(2) uniform field of illumination
(3) " diffusing medium.
(4) best tube focus possible to get sharp gradients
(5) good resolution on radar system.
(6) developed limiter which does not reduce the small signals but acts on the stronger ones to greatly reduce the range of possible contrast so that max of about 20% is limit.
(7) development of good (high contrast for low beam current) very slow tube.

The normal ~~slow~~ pure KCl is not any too slow for the present application considering the above.

My plan for immediate future is following:
(1) Make pure KCl tube room temp evap.
(2) " KCl tube with very small amount of Th (about .01%) so that decay will not be speeded up but so that main impurity is an active metal and not some

unknown chloride.

(3) Exp. with putting deposit down on warm surface in order to produce a stable surface with very slow decay for weak signals.

This means that our search for the stable-fast tube is set aside for the present in order to get formula for best tube as now needed in systems like the Spray cliff and Fishes Island systems.

Notes on Trip to Fisher's Island
May 18, 1944

Persons present: T. Soller, Radiation Laboratory
H. C. Kelly, " "
A. Y. Bentley, " "
W. B. Nottingham, " "
Hartley Lyman, G.E., Bridgeport
L. E. Swedlund, RCA, Lancaster
C. Moore, Fisher's Island Station

There were two systems operating at Fisher's Island both working from a radar system operating in X-band with a 500 cycle repetition rate. The spinner was running at approximately 5 r.p.m. The two systems were (A) the bath-tub type and (B) the original projection system with a vertical screen and no plate reflecting mirror. ~~Two more~~ Observation points with regard to the operation as found, are as follows:

System A.

1. Signal strength very strong giving high contrast for large echoes.

2. The "sawtooth" gain resulted in a sawtooth component of the bias.

3. The focus was not good. This was probably due to poor optical alignment and possibly due to a poor electron gun.

4. The illumination was quite non-uniform when compared with my memory of the uniformity found on English projection systems. The light intensity at the center of the screen seems to be about that used in the English projection system.

System B.

1. The focus found in this system is obviously better than that of System A.

2. Signals much too strong.

3. Owing to sawtooth gain and bias, there is considerable color due to noise and possibly d.c. bias from approximately the 25-mile range point to the edge of the tube.

4. The system is operating on a 50-mile range.

5. Appearance of the correction plate indicates considerable dirt which must give objectionable light scattering, thus reducing effective contrast.

6. Dirt marks on concave mirror seem to indicate that it has been washed.

7. Tube in operation is No. 2974.

unknown chloride.

(3) Exp. with putting deposit down on warm surface in order to produce a stable surface with very slow decay for weak signals.

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The following is a log of the tests carried out during the afternoon. Times are noted in order to give an idea as to the length of time required for each test.

13:52 Tests being made on System B. Former mercury light removed and replaced by 1000 watt incadescent lamp with glass heat absorbing filter. The light gives good intensity of surface illumination at the center but the distribution is not uniform and falls off considerably at the edge. Signals on the tube are those from previous operation.

13:56 ~~Deep~~ Heat filter taken out in order to assist along with the electron beam to cleanup old signals on the tube

14:01 Cleanup quite good as a result of these five minutes using heat, light, and electrons.

14:06 Heat filter replaced with tube quite hot. The heat filter changes the apparent color to one which seems to be more "white" than was the case without the heat filter. Signals coming on quite strong.

14:15 A ~~area~~ control has been connected to the sweep mechanism so that ships' motion can be simulated by a slow rotation of the pattern as produced on the face of the tube.

14:28 Strong signals from land leave a trail on this tube of 45° of arc at a range of approximately 10 miles.

14:29 The heat filter was taken out to see the effect of running the tube hot. The effect was most marked on the weak signals as would be expected.

14:33 Signals turned off and weak beam used to cleanup tube.

14:36 After considerable cleaning up, signals turned on show land blocks for approximately 15 seconds or more, therefore indicate that even at this high temperature contrast will build up.

14:42 Automatic rotation of pattern again in operation with land block trail about 5° instead of 45°.

14:52 Moderately weak signals are invisible at the end of 3 seconds. Operating the tube hot makes the weak signals effectively much weaker relative to the strong signals. This is certainly the wrong direction for maximum usefulness. The general impression that I get is that the sharpness of the signals is not as good as that seen on English projection systems.

15:18 Have been observing on set A and find that an airplane can be tracked in spite of the poor focus of this system. These airplane signals last 3 seconds or less. The strong land signals are very "burned-in". At the extreme range there were three signals from moving boats. These were not resolved, but when the same signals were examined on the P7 tube associated with this system, all three were very clearly distinct. This shows that the presentation in the bath-tub looses much of the precision made available by the radar system and improvement in both the

unknown chloride.

(3) Exp. with putting deposit down on warm surface in order to produce a stable surface with very slow decay for weak signals.

This means that our search for the stable-fast tube is set aside for the present in order to get formula for best tube as now needed in systems like the Spray cliff and Fishers Island systems.

electrical and optical focussing must be obtained before this system can compete with P7 presentation.

15:21 The use of paper for the diffusing screen seems to be inferior to the acitatee sheet used by the English. Any mottling due to unevenness in the paper is likely to result in a loss in definition for the weak signals.

15:22 The only limiters that seem to be in use on these systems are limiters to keep the grid from being driven positive.

15:42 Our Thorium tube No. 158 was put in.

16:02 This tube was taken out. The following is my reaction:

Owing to the poor optical alignment, focussing was good over approximately 1/3 of the area. The focus of the gun was "medium"; I have seen better and worse. Contrast seemed to be quite good in the quadrant for which the focussing was good. Signals which represent echoes returned from ships lasted three to five seconds. The permanent echoes seems to die out quite well but no tests were made using the rotational pattern system. It was quite obvious that the decay using this tube was much too fast for the particular radar system here

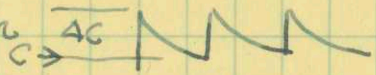
16:08 RCA tube No. CR-342-7 was installed. This tube has fresh screen KCl with 0.2% aluminum powder. Gun has limiting aperture, 36 mil grid hole and 180 mil limiting aperture hole. Grid drive test reported to give 30% contrast. Observations made using heat filter in place, gave signals from ships lasting three to five seconds. When the grid drive was carried to zero, some blooming was observed but at this point the contrast for these land signals was much stronger than is desirable.

16:38 RCA tube No. 324-3. Has 400 mil limiting aperture type of gun. KCl 500 milligrams plus 0.8% aluminum. 2 microampere cutoff at 42 volts. Contrast, 35% on 40 V grid drive and contrast ratio 24. With moderate drive focus on this tube, was just as good as previous tube but for a drive to zero bias, blooming was heavy, therefore, perhaps an indication that at zero drive there was more current in the beam than in the previous tube. Decay is much too fast for this radar system.

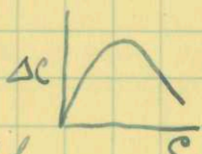
17:05 DuMont tube 5253-E installed. Focus quite good, general impression satisfactory in terms of the way in which the system is being operated.

It was quite evident from the general conversation that the idea of operating these tubes at low contrast levels has not made much progress. It seems evident that for the projection system to be successful improved resolution on weak signals will be necessary. This can be accomplished by an improvement in the optics and also in the illumination. A performance of the tube can be improved only by running the tube more or less as cool as possible and with the least possible contrast. This can be accomplished without serious sacrifice of weak signals by installing suitable limiters so that no signal produces a contrast greater than approximately 20 - 25%. Even the slowest tube tested was not too slow when thought of in terms of operation at low contrast levels.

May 29 '44 Talked to Bill Hope today when he came in to show me some rough plans concerning a research on DT screens which he proposes. He thinks that repeated rasters will give a pattern



which will have contrast $C+\Delta C$ at each beginning at C after a certain time. He also thinks that



the relations between C and ΔC should have a max. and that the ideal operating contrast would then be C_{max}. He wanted me to agree that this would be so. This does not seem to me to be the important factor. My view expressed to him is:-

(1) We should work at the <u>lowest</u> clearly observable contrast.

(2) We should operate with the smallest <u>range</u> in contrast above the min.

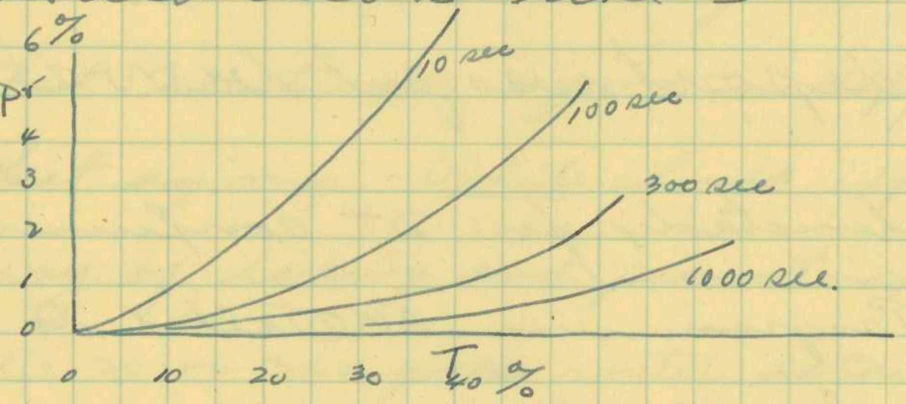
With these two conditions in mind a determination of the lowest observable contrast should be made and the min. length of time need for observation should be know. With these facts it is likely that the "best" tube will be the slowest operated at the lowest temp and observed at lowest contrast and contrast range.

Pointed out many of the difficulties of having Hopi's work be of much value unless carried on under "suitable" conditions and with the best tube etc. The work is properly in our field and not in his but we raise no objections on this point. We do object only on the grounds that it takes ~~them~~ him away from the problem of determining the min. observable contrast and discovering means of making this lower by improvement in focus and uniformity of focus, etc. We will study the decay properties when we discover how to make what we consider satisfactory tubes. This shows an example of the present state of very poor organization and coordination of all of our D.T. research at the present. ——

June 1, 44 Leverenz was here today to talk about some general problems of CR tubes. Discussed to some extent the fact that the metals have much more influence on screen properties than chlorides. Also mentioned to him the fact that we find surfaces put down at low temperature easier to clean up than those put down at high temp.

June 5, 44 Have been thinking about better ways of knowing a good "clean-up" tube from a bad one and have considered getting the following data.

Consider repeating a raster until a steady state is reached and then observe the decay after this series of excitation and do this at various values of Q. Curves should look like →



Note that these curves allow for the expression certain important properties of tubes. For ~~ex~~ample if 1% is the lowest observable contrast and we wish signals to fall to 1% in 100 sec. then the max signal strength assuming the above diagrams is 25% and in course of normal ~~ple~~ blocking in of land signals the time range for 10 sec. will be from 25% down to 3.3%. This shows that a 10% sig is the weakest which will show for 10 sec. Preliminary observations indicate that surfaces put down on the cold face plate (-35°C) can be operated to a much higher contrast and get clean up in 100 sec than the ~~no~~ tube in which deposit was put down at 65°C.

June 23, '44

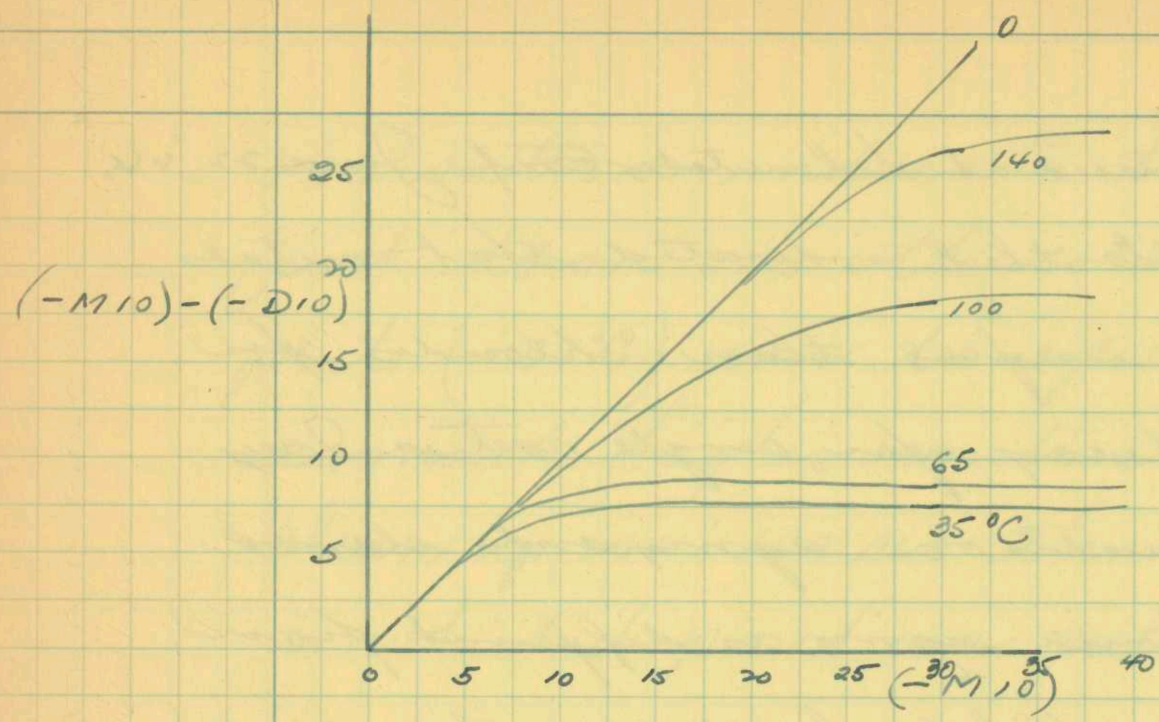
In Schenectady for D.T. conference yesterday. Program was AM ① Talked to Dushman 1 hr about pumps & vacuum before meeting. ② Seitz and his group reported data on Screen doping and aging generally to order of only 1 to 10 milli-coul. Data not very significant for present program. ③ Estermann showed that single crystals show decrease in contrast with time if exposed long enough to bombardment. This may be so but does not fit our observations on back reflection contrast from evap. screens.

We presented our data shown in the curve sheets 1 to 11 incl. called

"Data to be used at Schenectady Conf. June 22 '44."

Windsor
a Showed results that indicated that metals are more useful than chlorides for changing decay for single rasters. Ivey showed results on aging and claimed that electronic aging is different from heat aging. White showed exp. of a new way of taking and presenting data using 1 - 20 or 360 ~~puts~~ raster data. W.B.N. discussed the new ways of making tubes using deposit on cold face plate and showed by means of curves the advantages of these tubes over those using room temp deposit. Discussed the possibility of putting down part of the screen at room temp followed by the rest of the screen ~~at~~ at. Liquid Air temp. Told about using 2 evap. cups on -50°C. tube.

Kelly showed curves in which he plotted the contrast -M10 against ~~-D10~~ ((-M10) - (-D10) see sketch →



45° line 0-0 shows contrast for which (-D10) falls to zero. It is obvious that if the tube were operated at 140°C it would be practically impossible to drive a tube hard enough to give a single raster pattern that can be seen for any appreciable length of time to be useful.

(INTER-DEPARTMENTAL)

RADIATION LABORATORY

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

To: W. B. Nottingham November 14, 1944

From: W. B. Nottingham

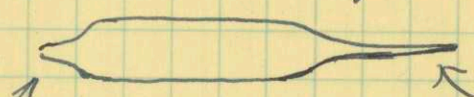
Subject: Notes on telephone conversation with R. L. Snider, RCA on 11/14/44

Mr. R. L. Snider, RCA, called in connection with the work that he has been doing on storage tubes. He was interested in getting suggestions concerning circuit arrangements for introducing into the signal circuit a compensation for the capacity coupling which must be expected between the cathode and the pickup surface. This of course, may be minimized by suitable shielding but apparently he has not been able to shield well enough to eliminate it and needs some compensation. I referred him to my paper in the Physical Review but advocated that the better solution would be to use a high fidelity amplifier to get his fast reversal. He said he had attempted that, but I suggested that he should use more degeneration and he would probably be able to do it satisfactorily that way.

We also discussed the question of evaporating material onto the surface and he suggested that he would perhaps try depositing the material in particle form. I feel that that would not be as satisfactory as evaporation and called attention to the fact that cadmium tungstate might be a good material to use.

1/30/43 As a result of yesterdays' reading, (see p8) it seems that an experiment with a good low pressure oil of index of refraction of about 1.49 which followed steps below :-

(1) Prepare a vial and distill into it the oil under the best vacuum conditions. The shape might be like this



(2) Build a DT tube of the usual design either with a face plate or in a flask but with a side tube for the unbroken vial

(3) Operate the tube to get a measure of the contrast by back reflection.

(4) If the technique of measuring transmission contrast could be developed it would be important to do this too.

p8)

5. After contrast measurements are made the vial should be broken and the two contrasts again measured after a film of oil was allowed to flow over the KCl surface. (It might be necessary to hold the tube in the vertical position for measurement.)

6. We should expect very little change in the transmission darkening or contrast as measured by comparing two areas close together one of which had color centers and one without. We should expect a big change in the amount of "back reflected" light and also a reduction in the measured contrast by back reflection.

Feb 2 '43

Telephone call to Leitz - Arrange to have Loewing come to Schenectady 2/8/ also Eastman is cleared. See Report on Conversation 62-TS-0202

Letter from Dushman 1/29/43 to Bacher carried copies of two letters Johnson to Dushman dated 12/8/42 and 1/26/43. Subject "KCl on heated Glass" Main points:-

(1) ~~Jt~~ Johnson + Jams saw "white stuff" several months prior to 12/8/42

(2) Not an impurity but KCl on hot glass gives much scattering of light in proportion to its thickness when compared with putting it down cold.

(3) Thickness of hot deposited film cannot be judged by it light scattering.

(4) Think that my estimate of KCl thickness is off by 100.

(5) Attempts to explain "anomalously opaque film" by letter of Nov 20 "that crystallites are randomly oriented, are large, and probably less compacted (?) than those

of films deposited at lower temp.

My letter of Dec. 7 computes 1 mg/hr for our evaporators at 500°C

A 6×10^{-4} cm (6 micron) thickness would give about 1 mg/cm²

Item (4) if true would make the thickness 6×10^{-6} cm – The wave length of green light is 5.5×10^{-5} cm and therefore Johnson at one point takes the film to be so thin that it is $\frac{1}{10}$ the wave length of light and at another point ~~the~~ (in 5) he explains his ideas in terms of "large" crystals.

It seems to me that a "film thickness" of about 10^{-4} cm would be about the minimum for good back scattering.

(6) Johnson states that he thought "that anomalously large light scattering - - - "was generally well known. He also seems to think that the sketches in my letter covering tube 41409 show the same thing.

The following has to do with the 1/26/43 letter. —

(1) Objects to our not abandoning the possibility that "white stuff" is an impurity.

(2) Claims that exp. using el. diff. show "no evidence for any material other than KCl in any deposit."

(3) Has found Non-KCl ~~patterns~~ rings on 5 or 6 patterns - Amount of unknown not more than five percent.

(4) Deduces that less than 300 mg. were put in pots for tubes analyzed by Lievering.

Facts were.

	W. Stuff. Deposit	KCl	Over 30 min
X-14	1.3 mg.	414	440-490
X 15	2.5 "	575	440-490
X-17	1.4 "	450	450-500

These figures would seem to indicate a rate of evaporation of 5 times that of KCl. —

OFFICE FOR EMERGENCY MANAGEMENT
OFFICE OF SCIENTIFIC RESEARCH AND DEVELOPMENT
1530 P STREET NW.
WASHINGTON, D. C.

VANNEVAR BUSH
Director

March 8, 1945

Prof. Wayne B. Nottingham
Department of Physics
Massachusetts Institute of Technology
Cambridge 39, Massachusetts

Dear Professor Nottingham:

I wish to acknowledge your letter of March 6 and the accompanying memorandum suggesting new means of communication. I have not been following the work within this Office on this subject closely and hence I am not in a position to comment personally on the novelty or usefulness of the proposal. However, I am glad to have this suggestion and am passing it to the Chairman of NDRC for review by the appropriate NDRC group. If these ideas are of interest to that group you may expect to hear from them directly.

Very sincerely yours,

V. Bush

V. Bush,
Director.

COPY

March 6, 1945

Dr. Vannevar Bush
OSRD
1530 P Street, N.W.
Washington, D. C.

Dear Dr. Bush:

Yesterday Prof. P. M. Morse mentioned to me the fact that Prof. Chaffee is undertaking to establish a research group to develop new means of communication. As a result of that stimulation I thought of a means which would be new as far as my experience goes. I have written the essential features of this method on the enclosed memorandum, which it was my intention to give to Prof. Chaffee when I see him Friday afternoon, March 9.

Prof. Slater suggested that I discuss the problem with Mr. Sage and as a result of my discussion with him, I am sending a copy of my disclosure to you. It would not surprise me if this idea were already covered and therefore, it will probably be of very little interest to you. If by any chance you are interested and would like to have someone discuss with me the technical difficulties which I am sure will be considerable, I shall be glad to be of any service that I may.

Very truly yours,

Wayne B. Nottingham
Professor of Physics

WBN:EP

Enc.

copy 3

copy 2 to Chaffee

Copy #4 to Capt Fagal

rotor trace although the back reflection

March 6, 1945

Dr. Vannevar Bush
OSRD
1530 P Street, N.W.
Washington, D. C.

Dear Dr. Bush:

Yesterday Prof. P. M. Morse mentioned to me the fact that Prof. Chaffee is undertaking to establish a research group to develop new means of communication. As a result of that stimulation I thought of a means which would be new as far as my experience goes. I have written the essential features of this method on the enclosed memorandum, which it was my intention to give to Prof. Chaffee when I see him Friday afternoon, March 9.

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Very truly yours,

Wayne B. Nottingham
Professor of Physics

WBN:EF

Enc.

copy 3
copy 2 to Chaffee
copy 1 to Capt Fogel

COPY

TO: Whom it Concerns March 6, 1945

FROM: W. B. Nottingham

Consideration has been given to the use of a storage tube in connection with the development of moving target indicators. One attempt to use a storage tube was undertaken about the middle of June 1944. A brief report of the results was made to the writer on October 18, 1944. The story about this is written up in Computation Book 1320, Page 114. In October the writer made the suggestion that instead of using a surface of glass as was originally done in June, a film of insulating material could be evaporated onto a suitable conducting plate to form the storage surface. Although this was written up on form DC-S-A, no attempt has been made to try this idea out in connection with the development of an MTI system.

It now appears that this idea might possibly be useful in connection with security communication. Assume that a cathode ray tube is constructed with a metal plate inserted in the end of the tube normally occupied by the fluorescent screen. Upon this metal plate is deposited a highly insulating material of extreme uniformity and relatively low sticking potential, as defined in terms of the secondary emission property of insulators. For example, it is thought that the sticking potential of calcium tungstate is probably about 3000 volts. This means that if the cathode is 3000 volts negative with respect to ground and the normal conducting wall coating of the cathode ray tube is 500 volts positive with respect to ground, then with a uniform electron beam scanning a rectangular raster over the surface of the insulator the entire plate will tend to come to that potential which is the sticking potential of the insulator, which, in the case just described, is ground potential. The surface acquires this potential because the secondary emission yield becomes exactly equal to one. That is, one secondary electron is emitted for each primary that hits the surface.

Suppose now that the metal surface is connected through a suitable highly insulating capacity to ground, and the potential of the CRT cathode is modulated with respect to the average value of -3000 volts by means of a code signal or even voice signals. Furthermore, I assume that a pair of deflection coils will cause the electron beam to sweep back and forth across the insulated plate by means of a linear sweep of approximately 10 centimeters per second, and a vertical step-like sweep which would move the beam at right angles to the fast sweep about 0.02 centimeters per step. If we assume ideal conditions, then we would obtain traced across the receiving surface a variation in potential which would be a replica of the signal imposed upon the cathode.

For the transmission of this signal the cathode would be held at a constant potential and the coupling condenser mentioned above would be connected to the grid of an amplifier. High speed sweeps would be used to sweep the surface that has the stored information. It is not unreasonable to suppose that the entire raster could be covered in approximately 20 milliseconds. As the beam moves from point to point, signals will be generated in the grid of the amplifying tube, and after suitable modulation these signals may be transmitted by radio and received. Following suitable de-

COPY

March 6, 1945

Dr. Vannevar Bush
OSRD
1530 P Street, N.W.
Washington, D. C.

Dear Dr. Bush:

Yesterday Prof. P. M. Morse mentioned to me the fact that Prof. Chaffee is undertaking to establish a research group to develop new means of communication. As a result of that stimulation I thought of a means which would be new as far as my experience goes. I have written the essential features of this method on the enclosed memorandum, which it was my intention to give to Prof. Chaffee when I see him Friday afternoon, March 9.

Prof. Slater suggested that I discuss the problem with Mr. Sage and as a result of my discussion with him, I am sending a copy of my disclosure to you. It would not surprise me if this idea were already covered and therefore, it will probably be of very little interest to you. If by any chance you are interested and would like to have someone discuss with me the technical difficulties which I am sure will be considerable, I shall be glad to be of any service that I may.

Very truly yours,

Wayne B. Nottingham
Professor of Physics

WBN:KP

Enc.

copy 3
copy 2 to Chaffee
copy #1 to Capt Sage

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modulation at the receiver, the signal is again used to modulate the cathode of a storage tube, similar to that used at the transmitting station. At the receiving station immediately after the recording of the signal has taken place, the storage tube may be scanned using a constant cathode potential, and the slow sweep and the output signal re-expanded in time so that it becomes a voice reproduction or a code reproduction of the original information introduced by the sender.

It is easy to see that if this system of communication could be worked out it would have the property of requiring the transmitting station to be "on the air" an extremely short period of time in order to transmit the information that required about eight minutes to record. If only thirty seconds are required to record the original message, then the recording and reproduction would require a total time of approximately one minute. It is self-evident that the total time required for the transmission of a message and its ultimate reproduction will be not less than twice the time needed to record the message.

The fact that storage tubes have been suggested for the MTI is an indication that many others besides the writer have thought about the possible application of such tubes. The use of the tubes and associated sweep circuits for the transmission of voice or coded information is entirely new as far as the writer is aware.

Wayne B. Nottingham
W. B. Nottingham
March 6, 1945
Cambridge, Massachusetts

The above disclosure has been read and understood by me

John C Slater
March 6, 1945
Cambridge, Massachusetts

WBN:EP

color trace although the back reflection

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W. B. Nottingham
March 6, 1945
Cambridge, Massachusetts

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March 6, 1945
Cambridge, Massachusetts

WBN:MP

Johnson indicates that the vapor pressure of NaCl is lower than that of KCl which checks Kelly's values but does not agree with the B.P. in Rubber handbook which we used in first considering that the NaCl pressure was the higher.

Do not plan to reply to above since letters were not addressed to me and since we have no new evidence to offer. When this problem is better understood reference may be made to this

See page (80)

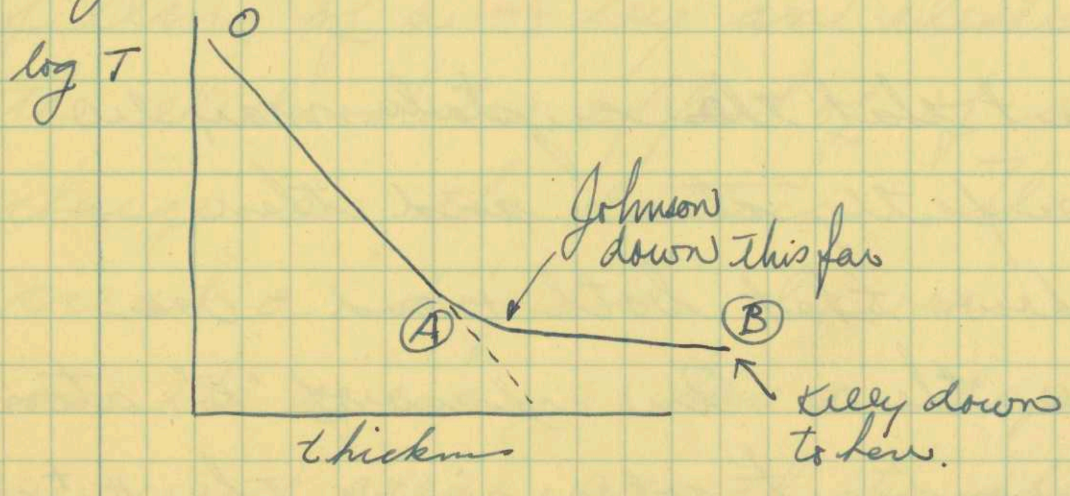
Kelly took a tube which had been open to air but still showed a color trace. He put "nujol" onto the surface and it became perfectly clear of back reflection but still showed the color trace although the back reflection contrast was greatly reduced.

Have just done an exp with R-9 using acetone - Will write up tomorrow.

May 28 '43

In Feb. the tests were made by pouring acetone onto the face of tube R-7 after it had been opened to air. Acetone makes the face transparent. A pattern which was there becomes nearly invisible while the surface is wet. After drying which takes place in a few seconds the surface and pattern are unchanged.

A conference was held here on May 25 At this Bushman showed some results ~~of~~ obtained by Johnson on the change in transmission with thickness of KCl. The log (Transmission) decreased linearly with the thickness up to about 0.755 ~~pe~~ mg./cm² at which the transmission was 10%. This continues up to 1.05 mg/cm.² Rate was .0125 mg/cm²/min. At the high rate of 0.15 mg/cm²/min, 10% was obtained at 0.87 mg and final layer was 3 mg/cm². Although conclusion was that transmission followed straight line the lower part of the curve actually bent over. This is in agreement with Kelley's data taken within the past month.



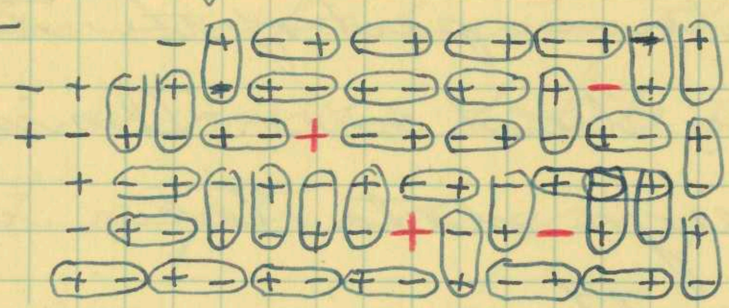
In order to establish the truth of Kelley's observations an exp should be done with part of the tube covered until the first deviation takes place at (A) then evap. K.Cl on whole tube to continue to and see if OA is repeated during the

the time (AB) is developed. This is one of the first "transmission" exp we hope to do.

June 24, '43

Within last few days have been thinking about some points as to mechanism of D.T. These were

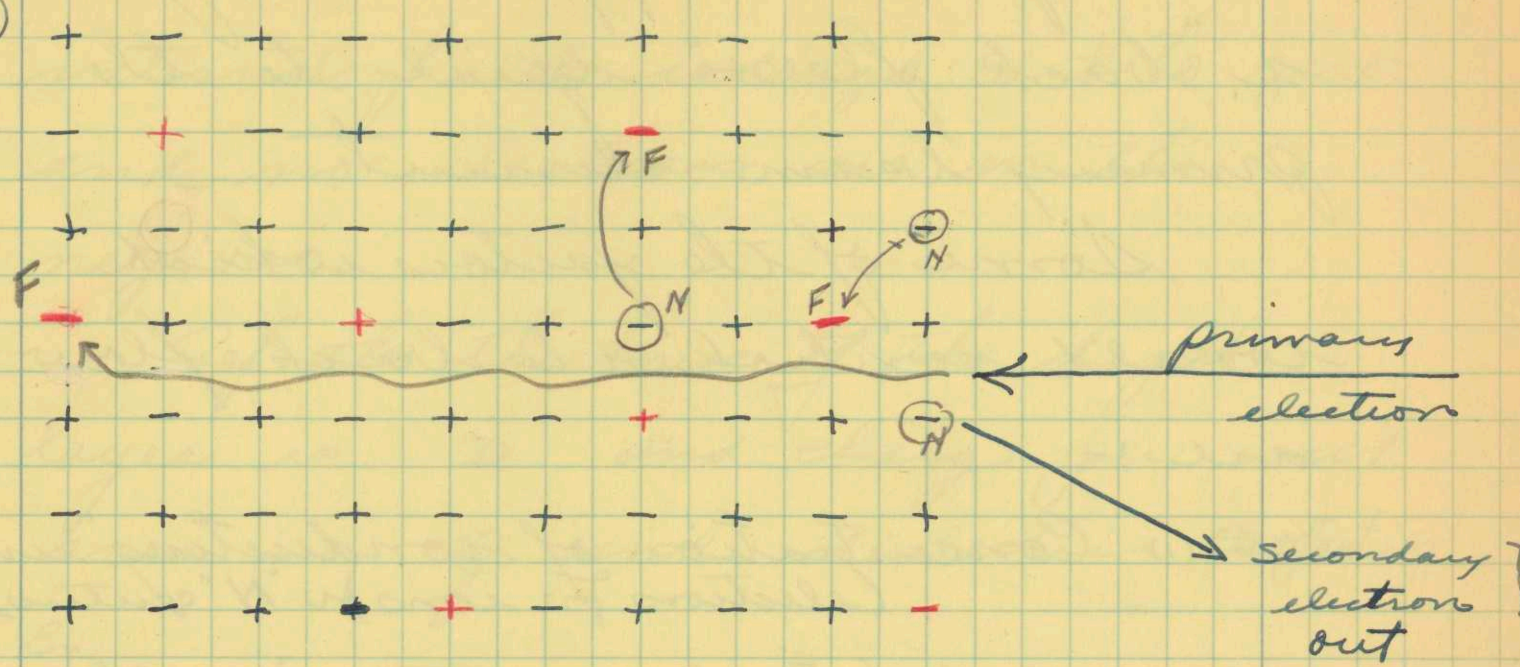
(1) Creation of lattice defects by arrangement of molecules. Illustrated below —



+ and − vacancies

(2) The fact that the crystals may be made perfectly clear and then excited shows that both + and − vac. must be there. An excess of "K" atoms gives permanent color since the K^+ ions would fill the + vac. and the electron would go into the − vac.

③



The removal of an electron from a chlorine atom creates an "N" center which as far as the crystal as a whole is concerned is the electrostatic equivalent of a positive charge in the lattice. The filling of a (–) by an electron produces the electrostatic effect of of a negative charge in the lattice. These two effects creat a "dipole" layer which on the average has a dipole moment per unit area equal to charge put in by the electron stream mult. by the penetration distance until the field developed is sufficient to give a "back flow" equal to the primary beam current.

Some of the factors which would control the "back-flow" are :-

(1) Concentration of conducting "units" (electrons or ions or "N" centers)

(2) Mobility of conducting "unit."

(3) Electric intensity.

The concentration of conducting units should be a function of

(1) Temperature

(2) ~~Fy~~ Light ~~falling on~~ flux

(3) Excitation of secondary electrons.

(4) Occupied F centers.

The mobility depends on

(1) Kind of conducting charge
 (a) Electron
 (b) ~~Ion~~
 (c) "N" center by electron jumps

(2) Temperature

(3) Impurities.

In the unexcited state the internal fields average out to zero and no electrons are in the neg. vac.

If the thickness of the dipole layer is D and charge per unit area is q and dielectric constant is ε

$$V = \frac{4\pi q D}{\varepsilon}$$ since the

electric intensity is $E = \frac{4\pi q}{\varepsilon}$

For our tests we put 1 μ coulomb into a sq. cm for a single pulse. This is 3×10^{3} e.s.u. per sq. cm.

$$\frac{3\times10^{3}}{4.8\times10^{-10}} = 6.25\times10^{12}$$ electrons per sq. cm.

Assume as an approx $\varepsilon \doteq n^2 = (\text{index})^2 = (1.5)^2 = 2.25$

$$E = \frac{300 \times 4\pi\, 3\times10^{3}}{~~2.25~~\ 5} = 2.3\times10^{6}$$

This would be the absolute max of el. intensity.

$V \doteq 3\times10^{-4} \times 2.3\times10^{6} =$ ~~1500~~ 700 volts.

With a conductivity $\sigma = 10^{-11}$ (ohm cm)$^{-1}$
which is the low value taken by Seitz. (Should be 10^{-16})

$i_{max} = 2.3 \times 10^{6} \times 10^{-11} = 23 \times 10^{-6}$ amp. per sq. cm.

with normal cond of 10^{-16} this is 2.3×10^{-10} amp/cm^2.

The micro coulomb put in could have been put in at a beam current of 100 μa over an area of 6×10^{-4} cm^2. This gives a current density of $\frac{100 \times 10^{-6}}{6 \times 10^{-4}} \doteq 170 \times 10^{-3}$ amp/cm^2

Time would be $T = \frac{10^{-6}}{.170 \times}$ = 6 μ seconds.

The Q value used is the equivalent of a sharply focused beam applied to the tube for 6 μ sec. with a beam current of 100 μ amp.

These calculations indicate that it would not be impossible to develop the large internal field of 2.3×10^{6} volts per cm for a very short time since the back flow would be $\frac{23 \times 10^{-6}}{17 \times 10^{-2}} = 1.3 \times 10^{-4}$ or .013% of the primary current.

If the secondaries increase the conductivity by 100 fold the max instantanious return current is only 1.3 % of the primary current.

Suppose that the initial conductivity is dominated by the secondary electrons.

n_s = number of free secondaries per unit vol.

There might be some meaning to the equ.

$$\frac{dn_s}{dt} = c\frac{i}{e}(N_- - N_N)^{(n_s - F)} - n_s(\alpha N_N + \beta H_-)$$

N_- = concentration of Cl_- in lattice

N_N = " " neutral Cl atoms due to secondary emission process.

$_0H_-$ = Con. of ~~an~~ neg ion vacancies.

H_- = " " " " " after some are filled with electrons.

i = primary current density

e = el. charge.

c = constant.

In order to get order of mag. assume that the rate of production of sec. is so great during the 6 μ.sec. that the losses may be neglected.

Find concentration of sec. when 1 μ cou is put in.

No. of primaries is 6.25×10^{12} ele.
Assume max of 300 sec. per primary.
this would be 18.75×10^{14} sec.
Assume thickness of 3×10^{-4} cm.

$$\frac{18.75 \times 10^{14}}{3 \times 10^{-4}} = 6.25 \times 10^{18} \text{ sec. el. per c.c.}$$

Density of K.Cl = 1.984 Mol. wt. 74.55 gr/mol.

$$\frac{74.55}{6.06 \times 10^{23}} = 12.3 \times 10^{-23} = \text{gm / molecule.}$$

$$\frac{1.984}{1.23 \times 10^{-22}} = 1.61 \times 10^{22} \text{ mols / c.c.} = N$$

The average spacing between Cl–

$$(1.61 \times 10^{22})^{-1/3} \doteq 4 \times 10^{-8} \text{ cm}$$

$$\frac{6.25 \times 10^{18}}{1.61 \times 10^{22}} = 3.9 \times 10^{-4}$$

$\doteq .04$ % of Cl– would be ionized

For practical purposes take .2 mg per micron per cm².
4" bulb. 4 × 2.5 = 10 cm; area = 25 × π ≐ 78 cm²
15.6 mg per micron on 4" blank.

It seems from this that the relationships between the concentration of neg vac. or ($_0H_-$) and the (H_H) would be important.

After the secondaries are produced there is the problem of the relative transition probability to the H_- as compared with the H_H. The fact that films bleach when energy (light or heat) is applied shows that the "ionization" potential of a Cl_- is greater than the "ionization" potential of an "F" center, which is probably not far from 2.2 volts.

What is the energy required to excite a "Cl" electron? Absorption sets in strongly at 1800 Å (See Seitz Book p 410)

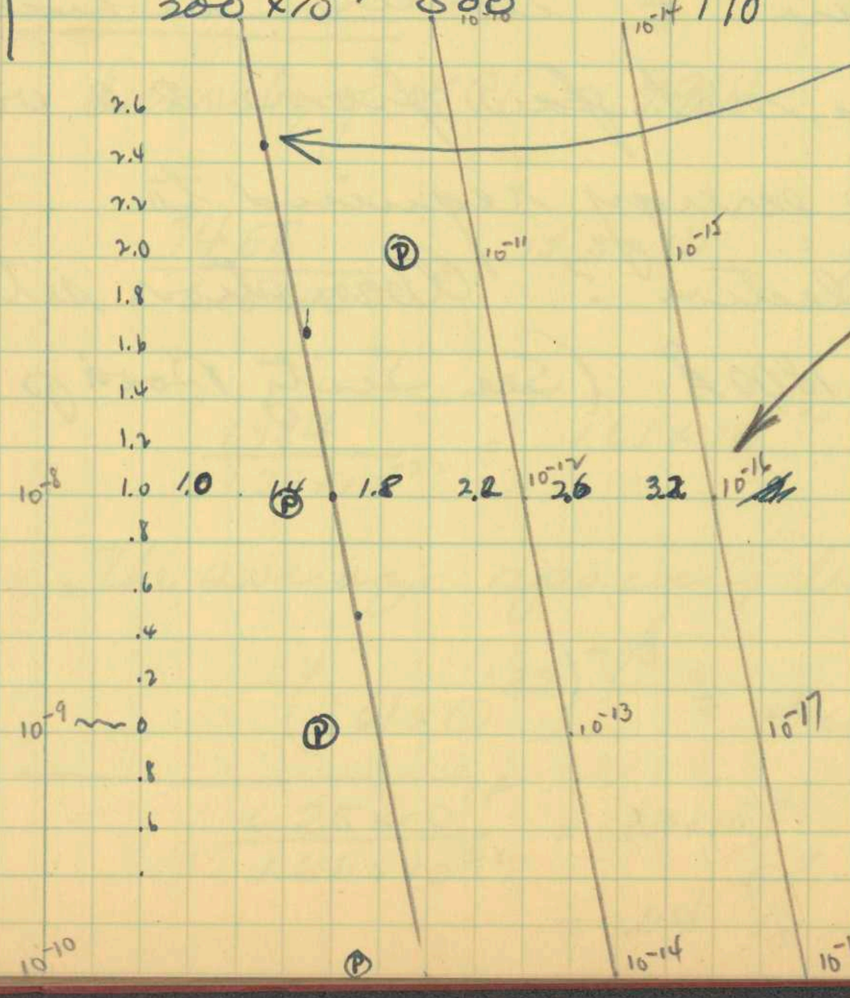
July 2

Some properties of KCl. Internation C. T.

I.C.C.	~~Mol wt~~	74.55
1:154	Density	1.988 gm/cc.
3:43		
1:54	Melting point	770. °C
	Boiling point	1416 °C
	Ref. Index	1.4903
	Xray - unit cell	6.28 Å
6:77	Dielectric const ϵ_0	5.03 (4.68 Mott + Gurney p 12)
5:418	Dissociation	4.5 el. volt. (1 ev is 23,000 g-cal per mol)
	Electron affinity KCl	87.1 (k-cal) = 3.8 e.v. (Mott + G. p 8)
	Natural freq. of vib of ions	10^{12}-10^{13} cy/sec (Mott + G. p 11)

For conductivity see Seitz p 55. (Look up W. Lehfeldt Z Phys 85, 717 (1933))

	Read σ	t	T	1/T
.49	3.1×10^{-9}	300°C	570	1.7×10^{-3}
1.0	10×10^{-9}	350	620	1.61
1.70	50×10^{-9}	400	670	1.49
2.49	300×10^{-9}	500	770	1.30



Room temperature would come about here and this gives 10^{-16} for σ instead of the value of 10^{-11} assumed by Seitz on page 7 of Manuscript.

Seitz uses 10^{-16} on page 5 of manuscript.

Ⓟ stands for Phipps data J. of Am Chem Soc. 51, 1331 (1929)

The T.E. Phipps + E.G. Partridge data show a conductivity characteristic which is much steeper than Lehfeldt and would therefore come to a still lower conductivity at room temp than 10^{-16} (ohm-cm)$^{-1}$
A good guess would be 10^{-18} (ohm-cm)$^{-1}$
equation is

$$K = A e^{-\frac{\varepsilon}{kT}}$$

Phipps expresses ε as ~~16~~ 15.7 $\times 10^{-13}$ erg per ion
or 22,800 cal/g ion.

July 9 '43 The above considerations lead to the picture that the "transient" trace might be ascribed to the **secondary** electrons in V_- (neg vacancies) and the relatively rapid return is the recombination with the Cl atoms from which they came.

The "permanent" trace could be due

to the primaries which shoot so far from the surface cl atoms that they remain until the integral of the "back-flow" current is equal to the "in flow". The instantaneous back flow current should be

$$i = E\sigma$$

where E and σ are a function of time and other conditions.

July 13 '43 Before working out some equations for the decay I want to write down the following relations which might hold:—

Assume that the back reflection contrast is produced by the absorption of light in the color centers which lie in a thin shell of ~~of~~ the KCl near the surface exposed to the electrons. The absorption will be determined by the concentration of ~~F~~ F centers and the length of the path through this region. If multiple internal reflections take place then a path length of 4 times the electron penetration thickness is not impossible.

Let λ_e = electron penetration depth.

" d = the average distance which the back reflected light travels through the darkened region

$$\left(\frac{d}{\lambda_e}\right) \doteq 4.$$

$$\lambda_e \doteq 3 \times 10^{-4} \text{ cm}$$

$$d \doteq 12 \times 10^{-4} \text{ cm}$$

Let β_c = the abs. coef. per unit path length.

Q_3' = light flux reflected back to measuring equipment when no color centers are there.

Q_3'' = Same as above with color centers.

$$\text{Contrast} = C_3 = \frac{Q_3' - Q_3''}{Q_3'} = 1 - e^{-\beta_c d}$$

When measurements are made Q_3' is measured directly with a known gain expressed in cb. For example gain is set at 400 - 20. This gives 380 as light for unit deflection with full gain as cb_1. Suppose attenuation of Δcb is used and observed "d" is d_3'

Q_3' in cb is $cb_1' + \Delta cb' + 100 \log_{10}(d_3')$.

In normal operation this light is balanced out

$$Q_3' - B = 0$$

Darkening is put on and Q_3 is obtained with $Q_3 < Q_3'$ and

$$\therefore\ Q_3 - B \neq = -|d_3| \neq 0$$

The value of $(Q_3 - B)$ in cb is

$$cb_1 + \Delta cb + 100 \log_{10}(d_3)$$

$$100 \log_{10} \left\{ \frac{Q_3' - Q_3}{Q^{3'}} \right\} = cb_1 + \Delta cb + 100 \log_{10}(d_3) - [cb_1' + \Delta cb' + 100 \log_{10} d_3']$$

$$= (cb_1 - cb_1') + (\Delta cb - \Delta cb') + [100 \log_{10}(d_3) - 100 \log_{10} d_3']$$

$$= 100 \log_{10} (C_3)$$

$$C_3 = 1 - \frac{Q_3}{Q_3'} = 1 - e^{-\beta_c d}$$

$$\frac{Q_3}{Q_3'} = e^{-\beta_c d}$$

$$\ln \frac{Q_3}{Q_3'} = -\beta_c d$$

$$100 \log_{10}(1 - C_3) = -100 \log_{10} Q_3 + 100 \log_{10} Q_3' = + 43.43 \beta_c d.$$

Talked to Ivey about method of calculation now in use. They compute M defined by

$$M = \log^{-1} \frac{(\Delta cb' - \Delta cb) + (cb_1' - cb_1)}{100}$$

and compute C in percent

$$C = \left(\frac{d_3}{d_3'} \times \frac{1}{M} \right) 100$$

Discussed question as to need of using balance out method and whether or not this increase accuracy unless the illumination lamps are controlled to the corresponding accuracy. Or else the balancing current should be obtained from the lamps. instead of the inside lamp.

July 15 '43 In thinking over question of effect of conductivity on persistent trace it seems that it would be interesting to put down surface with KCl until most of it is on and then put down the last 10 to 15% with simultaneous evaporation of aluminum from a separate source such as a coil of tungsten wire with an aluminum bead. The idea is to increase the conductivity very locally inorder to eliminate the permenent trace which I think will always stay in the surface until a back flow of current takes place equal to the integrated forward flow of the primary electron beam. Planning to make a tube like this. Discussed plan today with A. B. White. ——

Jan 4 '44 Some notes about limiting aperature guns.

The total beam current of lim. ap. guns should follow the "cube law" since this is nearly the same as the P-7 gun. In some cases the beam current seems to follow a "square law." Assuming these as satisfactory representations and also that the cut-off for total current is the same as for the beam current we have:—

$$I_T = k_T G^3$$

$$I_B = k_B G^2$$

G = grid drive in volts from cut-off

$$I_B = I_T \left(\frac{k_B}{k_T}\right) \frac{1}{G}$$

On 12/3/43 Data were obtained from V.C. Campbell (Schenectady) on their L.A. tubes (.090") which plotted as

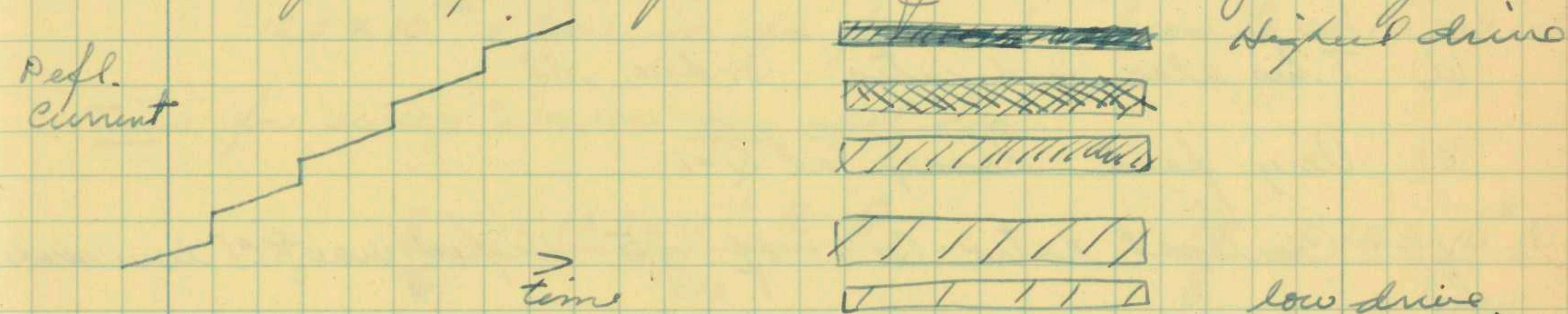
$$\frac{I_T}{I_B} = \left(\frac{k_T}{k_B}\right) G \quad \text{gave} \quad \frac{k_T}{k_B} = \frac{1}{17.3}$$

$$\therefore I_B = I_T \left(\frac{17.3}{G}\right)$$

Data on PN-44

June 23'44 - Putting in to production today a tube with 730 mg KCl in cup. Going to evaporate part ~~at~~ on room temp plate and ~~to~~ rest at liquid air temp.

Have talked to White & Ivey about a plan for cst. development to break raster into 5 strips by modification of 60~ sweep to get



These steps should be synchronized with changes in grid drive so as to excite tube to various extents. By using mirror scanning and photo tube, scope recording information may be obtained at a variety of Q values in a single raster. Visual observation ~~of~~ on time of disappearance would make a quick method of determining properties of tubes. Also after delivery of a large number of raster decays could ~~ab~~ be observed quantitatively and qualitatively.

6/24/44 Tube 174 was made yesterday with the first part of the KCl charge put down on plate at room temp and the last part put down at liquid air temp.

1st Results:—

(a) About normal back reflection but on low side (16%)

(b) Very low M at Q=1 Index 0.88

(c) Measured M " 3 = 20%.

(d) This also indicates Index .88

(e) Very fast decay at Q=1

(f) · Contrast ratio Q=3 of 25 Highest pure KCl ever made.

1st Conclusions:-

(a) The fact that index is same at Q=1 and 3 seems to indicate no abnormal volume scattering

(b) If the Q=1 contrast of 8.8% were low by about 20% i.e. M = 10.4

7/

7/4/44 Some equations concerning PPI operation were worked out for the conference of Oct 13, 1943. These were:-

Sweep vel. $$V_s = \frac{r_{max}}{12.3 \times 10^{-6} R} \text{ cm per sec.}$$

r_{max} = max radius of PPI in cm.

R = " range in nautical miles

12.3×10^{-6} = time in sec for radar beam to go 1 n. mile + return.

Time for sweep to move one spot dia.

$$\tau_\delta = \frac{\delta}{V_s} = \frac{12.3 \times 10^{-6} R}{r_{max}} \delta \qquad \frac{\tau_\delta}{\delta} = \frac{12.3 \times 10^{-6} R}{r_{max}}$$

δ = spot dia. in cm.

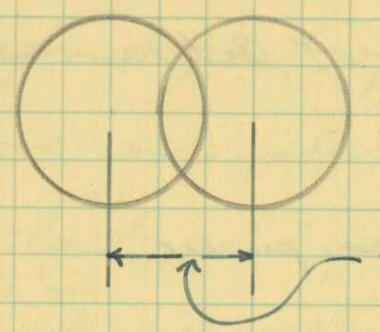
Current density

$$j = \frac{4i}{\pi \delta^2} = 1.27 \frac{i}{\delta^2} = 1.27 \frac{(AV^n)}{\delta^2} \text{ amp. per cm}^2$$

i = beam current in amp.

A = grid drive factor n = grid drive exp. V = grid drive volts. from extrap. cut off.

Some spot motion patterns (uniform dist over spot)



signal time = t_s = ~~p+1~~

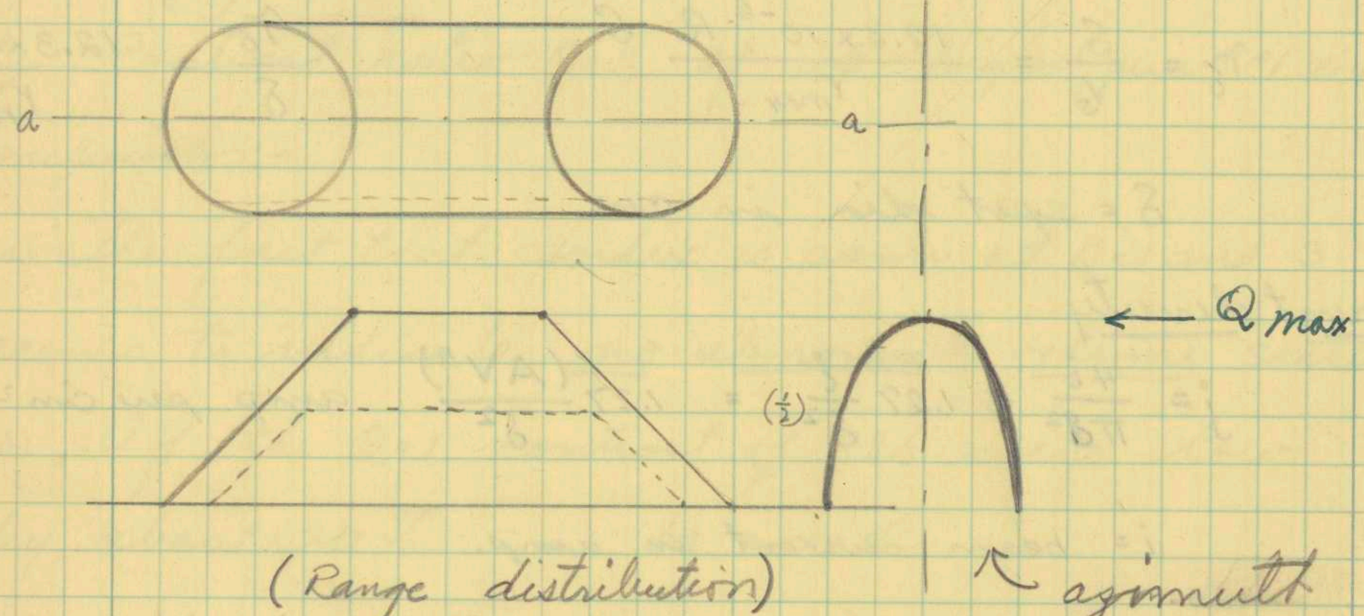
$$t_s = p + m \times 12.3 \times 10^{-6}$$

m = miles across object in any

A. No Overlap

Case I $\quad t_s > \tau_\delta$ gives max Q determined by (beam current)/(sweep speed)·(spot diameter)

$$Q_{max} = j\,\tau_\delta = 15.6 \times 10^{-6}\left(\frac{R}{r_{max}}\right) \cdot \frac{i}{\delta}$$

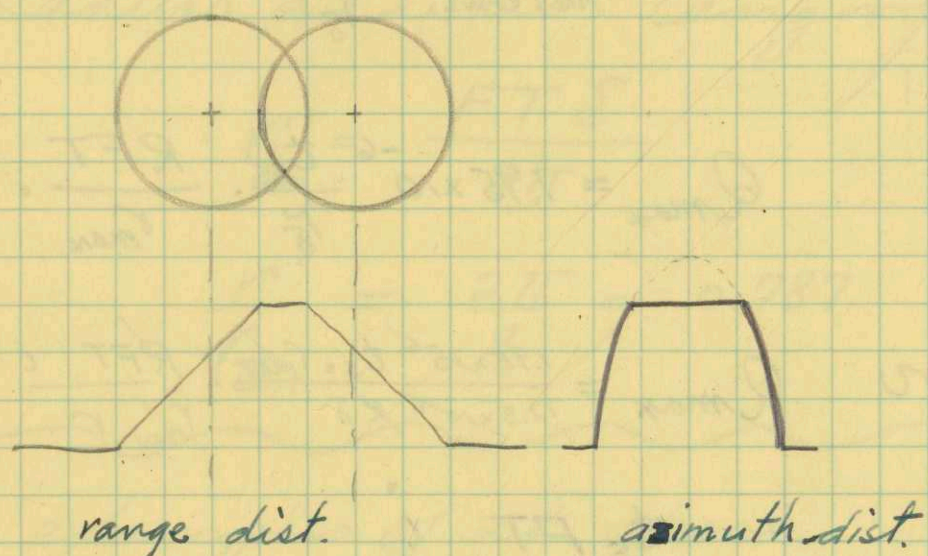


Decrease in spot size is only way of increasing ~~Q~~ contrast gradient for a given max Q. If sweep speed is reduced then current may be reduced for same

Q_{max} and with a reduction in current the spot size may be reduced and gradient improved.

No Overlap

Case II $t_s < \tau_\delta$

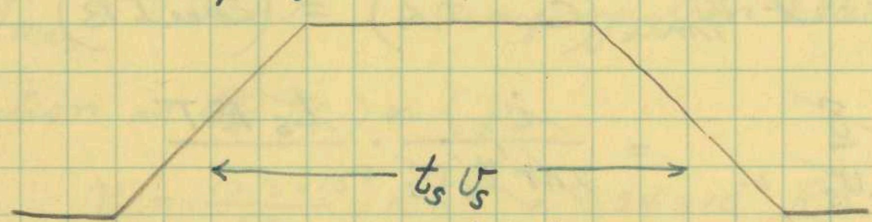


$$Q_{max} = j\, t_s$$

$$= \frac{1.27}{\delta^2} \cancel{\times 10^{-?}}\, t_s\, i$$

B. Complete overlapping

Case I $t_s > \tau_\delta$



Range distribution.

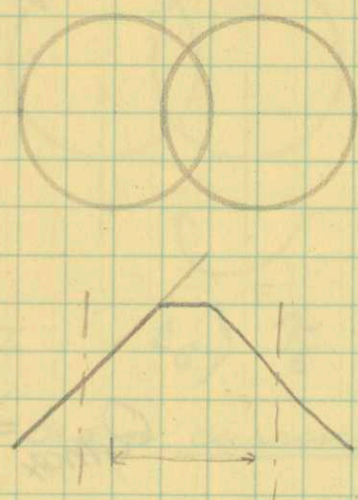
$$Q_{max} = \frac{i \int t\, dt}{\text{area}} = \frac{i}{2\pi r\, t_s v_s} \times t_s \times F \times T = \frac{12.3 \times 10^{-6}\, RFT}{2\pi r\, r_{max}} \cdot i$$

$$= 1.95 \times 10^{-6}\, \frac{RFT}{r_{max}} \cdot \frac{i}{r}$$

$$= \frac{\tau_\delta\, F\, T\, i}{2\pi r\, \delta}$$

F = rep. frequency T = rotation period.

Case II $\quad t_s < \tau_\delta$



$\leftarrow \; Q_{max\,\text{case I}}^{*} \times \dfrac{t_s}{\tau_\delta}$

$$Q_{max} = 1.95 \times 10^{-6} \frac{t_s}{\tau_\delta} \cdot \frac{RFT}{r_{max}} \cdot \frac{i}{r}$$

or

$$Q_{max} = \frac{1.95 \times 10^{-6}\, t_s \times r_{max}}{12.3 \times 10^{-6}\, R\,\delta} \cdot \frac{RFT}{r_{max}} \frac{i}{r}$$

$$= \frac{t_s FT}{2\pi r} \frac{i}{\delta}$$

How to determine "complete" over lap.

Case I $\qquad$ Set Q_{max} (Case IA) = (Case IB)

$$\underbrace{j\,\tau_\delta = \frac{4i}{\pi \delta x} \times \frac{\delta}{v_s}}_{\text{Case I A}} \quad = \quad \underbrace{\frac{i}{2\pi r' t_s v_s} \cdot t_s FT}_{\text{Case I B}}$$

Result $\quad r' = \dfrac{FT\,\delta}{8}$

Case II

$$j\,t_s = \frac{4i}{\pi\delta^2}t_s = \frac{t_s\,FTi}{2\pi\,r'\delta}$$

$$r' = \frac{FT\delta}{8} \quad \text{same as above.}$$

Radius at which tangent spots occur

$$r_{tan} = \frac{FT\delta}{2\pi}$$

$$\frac{r'}{r_{tan}} = \frac{2\pi}{8} = 0.787$$

Some examples of the above.

SK System –

$F = 60$ per sec. $T = 15$ sec.

$p = 5\,\mu s$ $R = 80$; 40 ; and 20 n. miles.

$r_{max} = 3.8$ cm (in projection $3.8 \times 8 = 30.4$ this is 12")

1st question is $\tau_\delta >$ or $< p$

$$\tau_\delta = \frac{12.3\times10^{-6}}{3.8}R\delta = 3.24\times10^{-6}R\delta$$

(a) $R = 80$ $\tau_\delta = 5\times10^{-6}$ for $\delta_5 = 1.93\times10^{-2}$ cm.
$= 40$ 5 " $\delta_5 = 3.86\times10^{-2}$ cm.
$= 20$ 5 $\delta_5 = 7.72\times10^{-2}$ cm.

Assume spot dia $\delta = 2\times10^{-2}$ then

R	τ_δ	for 1.8×10^{-2} ↓ τ_δ
80	5.18×10^{-6}	4.66×10^{-6}
40	2.59	2.42
20	1.30	1.17

This means that case I applies

overlap radius

$$r' = \frac{\overset{15}{\cancel{60}} \times 15 \times \delta}{\underset{2}{\cancel{8}}} = 112\,\delta$$

δ	2×10^{-2}	1.8×10^{-2}
	2.25 cm	2.02 cm

Case I A

$$Q_{max} = \frac{15.6\times10^{-6}}{3.8} \times \frac{R\ i}{1.8\times10^{-2}}$$

$$= 2.28\times10^{-4}\,R\,i$$

for $Q = 10^{-6}$

R	i	δ (I+W)
80	55×10^{-6}	1.2×10^{-2}
40	110	
20	220	1.3×10^{-2}

Case I B at 2 cm

$$Q_{max} = \frac{1.95\times10^{-6}\times 900\ Ri}{7.6} = 231\times10^{-6}\times Ri$$

with $R = 80$ & $i = 55\times10^{-6}$

$$Q_{max} = 2.31\times 8.0 \times 5.5 \times 10^{-6} \times 10^{-6} = 1.02\times10^{-6}$$

which checks above.

At 1 cm Q_{max} will be 2 for same current.

Note that these calculations are for the max. contrast and not an average contrast over the total area excited. This is where gradient considerations come in.

1760 yd in ~~land~~ statute mile.
2020 " " nautical mile.

164 yards per μ sec.

2nd Example

$F = 500/\text{sec}$. $T = 10$ sec.

$\rho = 10^{-6}$ $R = 30$ mi.

$\delta_{max} = 3.8$ cm. (System SWX)

determine τ_δ

$= 3.24 \times 10^{-6}\ 30 \times 1.8 \times 10^{-2} = 1.75 \times 10^{-6}$

This shows $\tau_\delta > \rho$

∴ For targets less than 0.061 n.mi (123 yards) case II holds for targets deeper in range case I holds.

Over lap radius $r' = \frac{500 \times 10 \times 1.8 \times 10^{-2}}{8} = 11.2$ cm.

shows complete over lap for all parts of tube.

Use case II B. —

$$Q_{max} = \frac{10^{-6} \times 500 \times 10\ \ i}{2\pi\ r\ \delta}$$

for $r = 3.8$
$\delta = 1.8 \times 10^{-2}$ $Q_{max} = \frac{i}{86}$

This shows that $Q = 1\ \mu c.$ at $i = 86\ \mu a$.

Half of this current is required at half the radius.

For targets bigger than 123 yards in range

$$Q_{max} = \frac{1.95 \times 10^{-6} \times 30 \times 500 \times 10}{3.8 \times 3.8}\ i = \frac{i}{49.4} \approx \frac{i}{50}$$

50 μa gives $Q_{max} = 1$

October 19, 1944

About a week prior to June 19, 1944 Dr. R. A. McConnell and an army officer to discuss the problems of "sticking potentials" as this term applies to my early studies of the secondary emission from insulators. This was discussed at some length and finally we made a tube for them on June 19. This tube was not tested because it was broken by them before tests were made. The tube was rebuilt on June 26, '44 and tests were made shortly after that but no report was given to us.

Yesterday (Oct 18, 1944) three R.C.A. men and two CESL men came in to discuss the fundamentals of this use of sticking potential method of storing information about radar signals. This was compared with some other methods and after this discussion they were more favorably impressed by the method than before our conversation. They reported to me that McConnell's tests were partially successful. This was my first news of it. The difficulty was that the glass was not uniform enough. I therefore suggested that a modification should be made in the tube which would create the insulated surface by evaporation. They asked for suggestions as to materials and I offered the suggestion of Calcium-tungstate since I knew from my early measurements that its sticking potential is low. If this material could not be used because of decomposition or for other reasons than ~~to~~ experiments should be undertaken to try quartz or any other material which could be evaporated. The advantage in using the evaporation method is that a uniform surface should result and therefore ~~a~~ much improved storage tube. I suggested the use of nickel, tantalum, or carbon as evaporator cup materials.

Form DC-5-A patent report was also filled out today to make this a part of the permanent record.

W B Nottingham

See p. 122 & 136 of book #2926.

The names of the RCA men were:- R. L. Snyder, J. B. Smith and M H Mesner.

and the CESL men were.

M. D. Ballar & Lt. C. S. Robinson.

June 30 '43 Small group conference held today between 62 and Lawson's group. Haworth spent most of time telling about P-7 measurements on test equ. and operating systems. These discussions seem to me to fall somewhat short of the mark because the factors of spot size and the statistical nature of the noise. This must be undertaken by some-one some-time.

Copy 4

chaffee + Bush
13

COPY

TO: Whom it Concerns   March 6, 1945

FROM: W. B. Nottingham

Consideration has been given to the use of a storage tube in connection with the development of moving target indicators. One attempt to use a storage tube was undertaken about the middle of June 1944. A brief report of the results was made to the writer on October 18, 1944. The story about this is written up in Computation Book 1320, Page 114. In October the writer made the suggestion that instead of using a surface of glass as was originally done in June, a film of insulating material could be evaporated onto a suitable conducting plate to form the storage surface. Although this was written up on form DC-S-A, no attempt has been made to try this idea out in connection with the development of an MTI system.

It now appears that this idea might possibly be useful in connection with security communication. Assume that a cathode ray tube is constructed with a metal plate inserted in the end of the tube normally occupied by the fluorescent screen. Upon this metal plate is deposited a highly insulating material of extreme uniformity and relatively low sticking potential, as defined in terms of the secondary emission property of insulators. For example, it is thought that the sticking potential of calcium tungstate is probably about 3000 volts. This means that if the cathode is 3000 volts negative with respect to ground and the normal conducting wall coating of the cathode ray tube is 500 volts positive with respect to ground, then with a uniform electron beam scanning a rectangular raster over the surface of the insulator the entire plate will tend to come to that potential which is the sticking potential of the insulator, which, in the case just described, is ground potential. The surface acquires this potential because the secondary emission yield becomes exactly equal to one. That is, one secondary electron is emitted for each primary that hits the surface.

Suppose now that the metal surface is connected through a suitable highly insulating capacity to ground, and the potential of the CRT cathode is modulated with respect to the average value of -3000 volts by means of a code signal or even voice signals. Furthermore, I assume that a pair of deflection coils will cause the electron beam to sweep back and forth across the insulated plate by means of a linear sweep of approximately 10 centimeters per second, and a vertical step-like sweep which would move the beam at right angles to the fast sweep about 0.02 centimeters per step. If we assume ideal conditions, then we would obtain traced across the receiving surface a variation in potential which would be a replica of the signal imposed upon the cathode.

For the transmission of this signal the cathode would be held at a constant potential and the coupling condenser mentioned above would be connected to the grid of an amplifier. High speed sweeps would be used to sweep the surface that has the stored information. It is not unreasonable to suppose that the entire raster could be covered in approximately 20 milliseconds. As the beam moves from point to point, signals will be generated in the grid of the amplifying tube, and after suitable modulation these signals may be transmitted by radio and received. Following suitable de-

modulation at the receiver, the signal is again used to modulate the cathode of a storage tube, similar to that used at the transmitting station. At the receiving station immediately after the recording of the signal has taken place, the storage tube may be scanned using a constant cathode potential, and the slow sweep and the output signal re-expanded in time so that it becomes a voice reproduction or a code reproduction of the original information introduced by the sender.

COPY

It is easy to see that if this system of communication could be worked out it would have the property of requiring the transmitting station to be "on the air" an extremely short period of time in order to transmit the information that required about eight minutes to record. If only thirty seconds are required to record the original message, then the recording and reproduction would require a total time of approximately one minute. It is self-evident that the total time required for the transmission of a message and its ultimate reproduction will be not less than twice the time needed to record the message.

The fact that storage tubes have been suggested for the MTI is an indication that many others besides the writer have thought about the possible application of such tubes. The use of the tubes and associated sweep circuits for the transmission of voice or coded information is entirely new as far as the writer is aware.

Wayne B. Nottingham

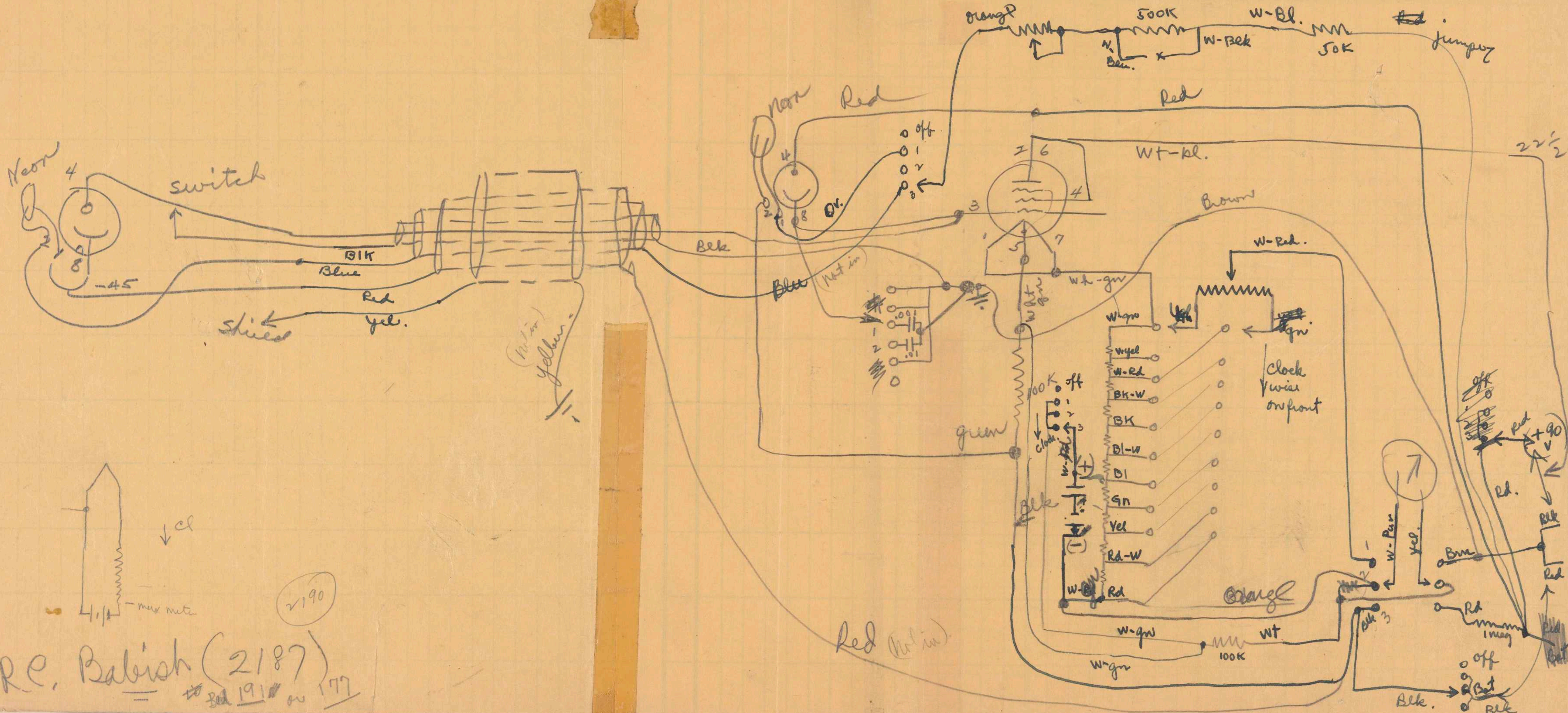
W. B. Nottingham
March 6, 1945
Cambridge, Massachusetts

The above disclosure has been read and understood by me

John C Slater

March 6, 1945
Cambridge, Massachusetts

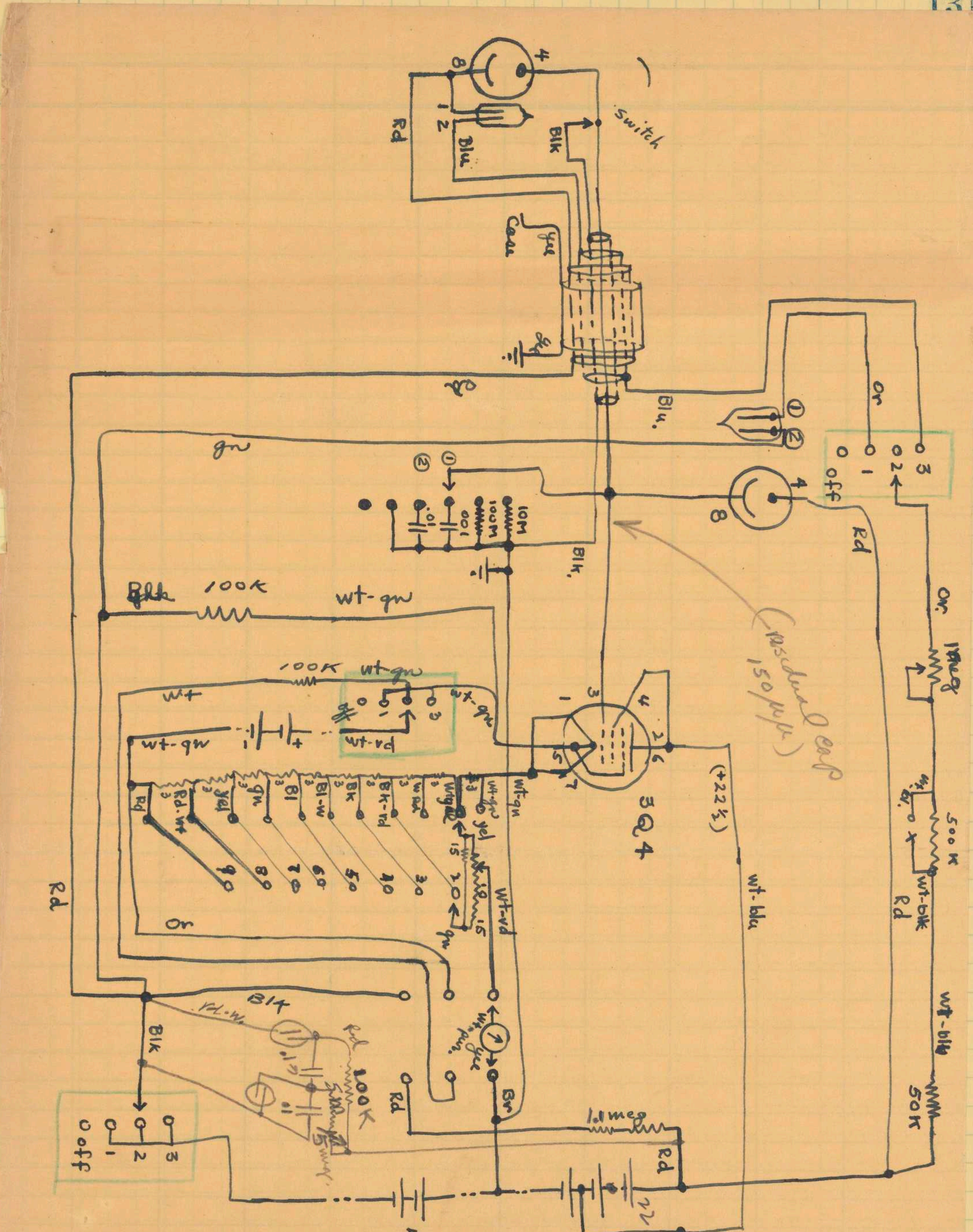
WBN:EP



v190

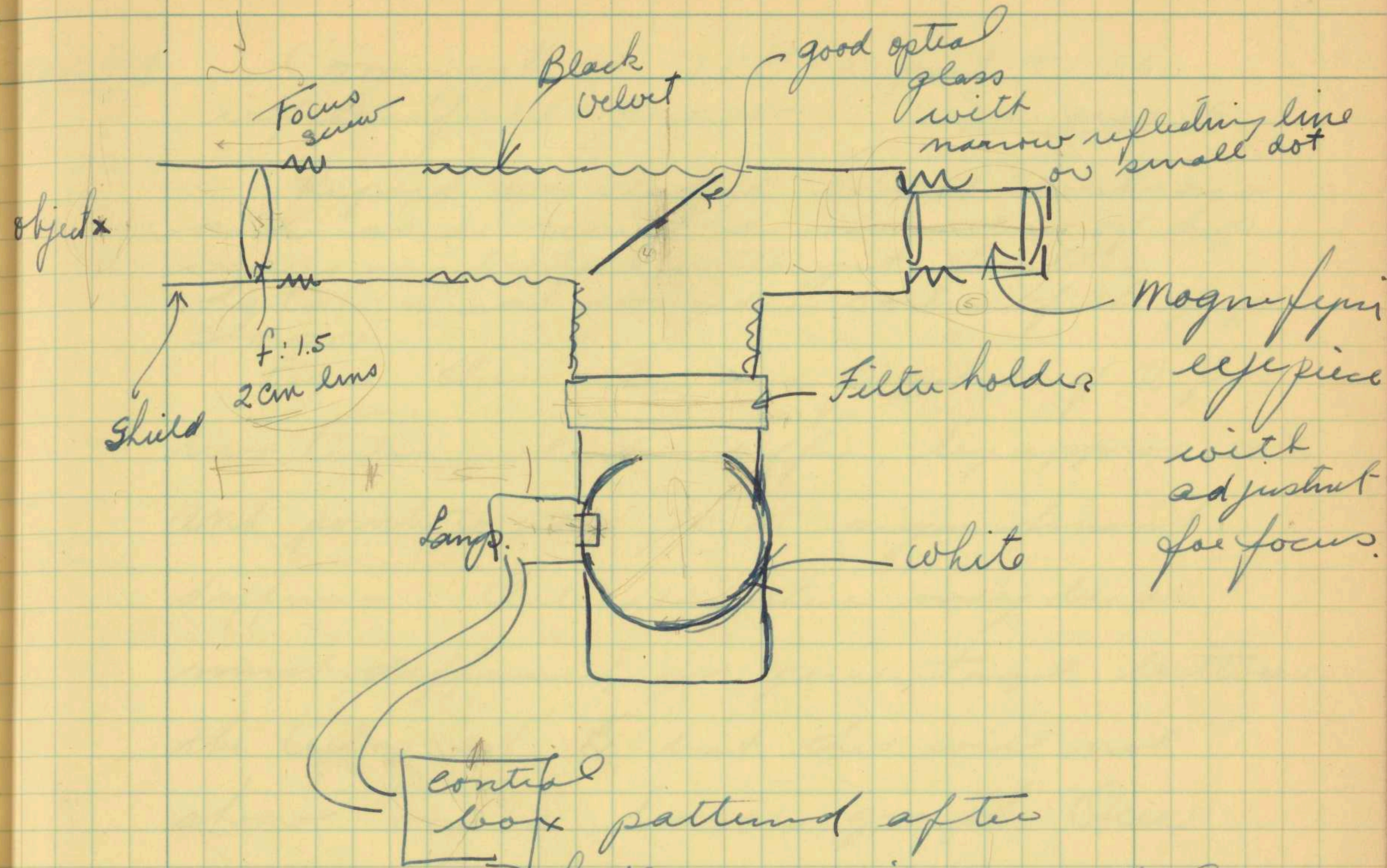
R.C. Babish (2187)

to Bld 191 or 177


Switch
Rd
Blu
Blk
gn
Blu.
Or
off
Blk.
100K
wt-gn
3Q4
(+22½)
wt-blu
Rd
Or.
1 meg
500 K
wt-blk
50K
wt-blk
1.1 meg
Rd
Blk
off
45
22
45
(residual cap 150 µµf)

Nov. 25, 1943 +

Some time ago C. Newton asked for help on an exposure meter for P-7 and other cathode-ray tubes. At the time it was thought that some photoelectric ~~and~~ pick up would be used. Last week Jesty (G.E.C.) was here and left his "Street Surface Brightness Meter Cat No Z 9900" here and this suggested the possibility of using a "pyrometer" principle for Newton's Job. Today I took the red filter out of our L+N pyrometer and found that an instrument of this type might possibly be developed for the purpose at hand. It would be worth while to take it up with Polaroid Co. as a possible producer.



pattened after L+N pyrometer control for intensity. —

Drawn Nov 25, 1943

2/23/44 Comments on TRE - report T-1550 by Bradfield + Garlick — See page 36

Report was studied about 3 weeks ago and as a result a number of exp. were undertaken to get further data. First consider some of the figs. shown.

Fig. 1 shows B_∞ as a function of Q for two tubes which differ by approx 20% and points to this as a significant difference. Actually there may be as much difference in percentage between the tubes at B_1 but this will not show on a linear graph. Our measurements on 15 or 20 tubes gives a max spread of only 20% in B_{100}. The actual differences in cb, are as much as 30 or more cb which is a factor of two in brightness.

There can bee no doubt about the fact that greater differences exist between tubes in their response to the first 5 or 10 hits (approx 100 microvolts.) than there is for 10 to 100 or more hits.

After a long period of "cyclic" excitation a considerable volume of the yellow component is excited and associated with moderate excitation of a large volume of phosphor in all states of decay in phosphorescence the apparent decay will be much less than the "characteristic" value

The following is of interest in connection with the decay after a prolonged excitation.

Suppose that the "true" decay follows the law

$$L = \frac{L_0}{(time)^n}$$

and that time is $t_0 + t$ where t is observed beginning at some time t_0 after the "true" time of decay started.

$$\ln L = \ln L_0 - n \ln t_0 - n \ln\left(1 + \frac{t}{t_0}\right)$$

The ~~log~~ slope of the log L - log t curve is use to define n. Note the following:–

$$\frac{d(\ln L)}{d(\ln t)} = -n \frac{d[\ln(1+\frac{t}{t_0})]}{d(\ln t)}$$

Let $\ln t = x$
$t = e^x$

$$\frac{d[\ln(1+\frac{e^x}{t_0})]}{dx} = \frac{1}{(1+\frac{e^x}{t_0})} \times \frac{e^x}{t_0} = \frac{1}{\frac{t_0}{t}+1}$$

$$\therefore \text{Slope } n' = n\left[\frac{1}{\frac{t_0}{t}+1}\right]$$

Even though n might be a constant the observed slope n' changes with the time and gives a value of $n' = \frac{1}{2}n$ at a time of observation $t = t_0$.

This shows that no significance can be attached to the decay constant n' when the observation is made at a time t after a long period of cyclic excitation since the t_0 is indeterminate.

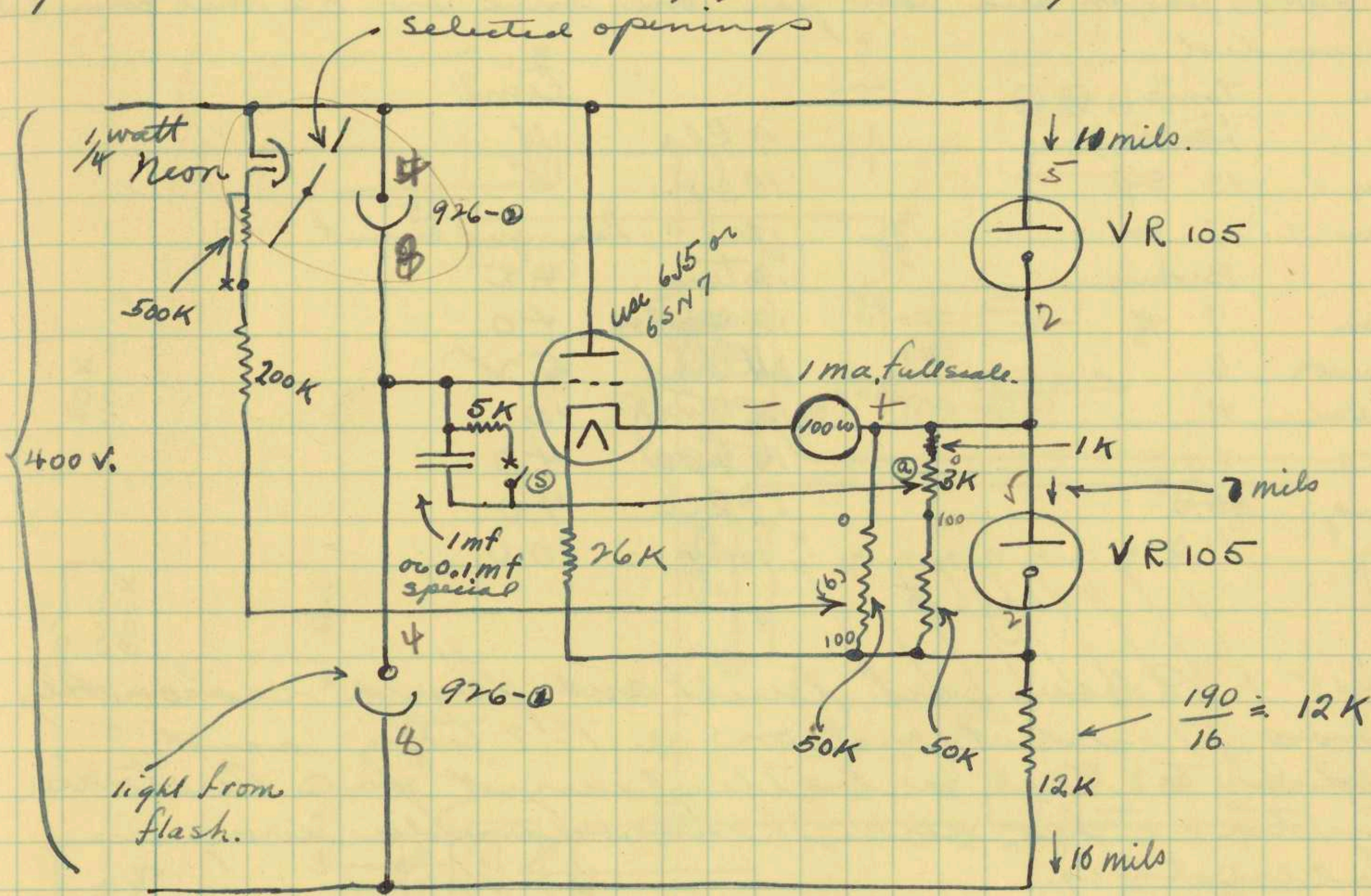
The next part of paper has to do with "Incremental Brightness" and so called "Signal - Noise" ratios. There is no disagreement with the experimental data but there is considerable room for differences in opinion as to interpretation. In this section Fig 5 and Fig 6 are of interest.

The location of the maximum of ~~#~~ Fig 5 depends on the Q of the "Blip" and shifts toward zero as the Q falls.

In Fig 6 two ratios are shown. One of these is the simple "brightness" ratio and the other is the "contrast" ratio. These differ ~~x~~ by the additive constant of 1.0. The fact that the "contrast-ratio" for one "Blip" is almost the same for all tubes

Jan 10, 1945

Talked to H. Edgerton about his circuit for integrating radiant flux from his flash sources. Suggested the following cct.



Take max over load as 4 mils.

$\frac{105}{4} = 26\,K$ as cathode res.

Stand by current is 4 mils in tube

Operation:

With switch closed ⓐ is adjusted to give meter zero.

With ⓑ at 0 drift of meter should be positive when ⓢ is open

with ⓑ at 100 " " " " negative " ⓢ " "

if not select opening or distance between neon and 926-② until above are satisfied

Find position of ⓑ for zero drift for reasonable time.

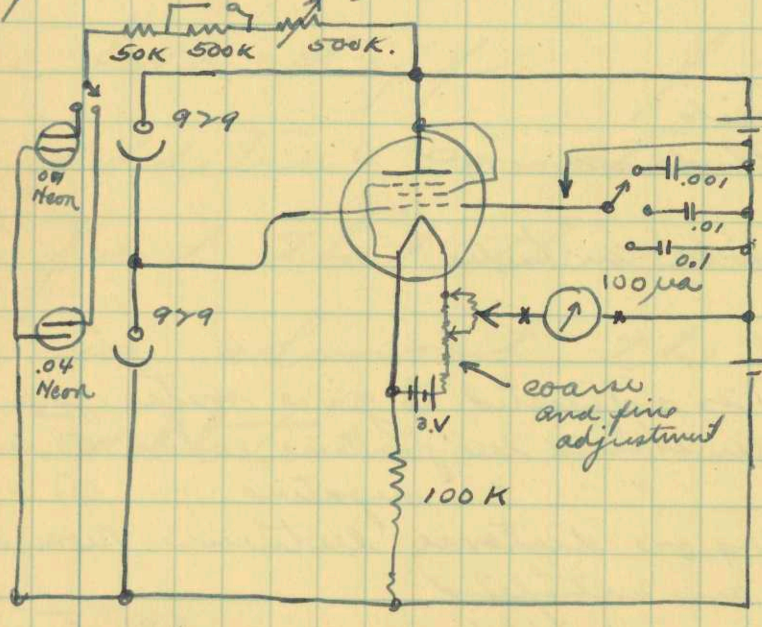
Short ⓢ then open and measure flash by exposing 926-①.

Jan 13 1945 circuit of 148 completed with result that grid current is greater than leakage current of 929. Ckt changed to use only one phototube and with lamp up set of 6SN7 put in and time for one mil or 0.2 mil com. tube up recorded.

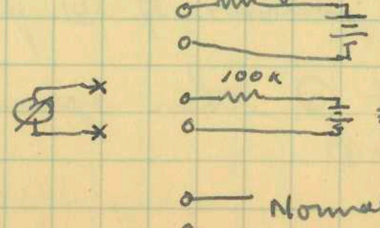
Tube	time		time
1	(~~16 Blue~~ 12)	9 Cla.	11
1 Sy	13 Sy	10 Syl.	5
2 Ken	7 Ken.	11 "	Large grid current
3	Broken.	12 tung.	4.2
4 Ken	9 K	13 ~~Sy~~ Ken.	4.0
5 Emerson.	6	14 tung	5.2
6 Ken	41	15 tung	10
7 RCA	4.0	16 ~~Ken~~	4.0
8 Tung.	~~15.0~~ 7.0	17 RCA	4.0
1 Sy.	11.0	1 Sy.	10.0

10 sy. 5.

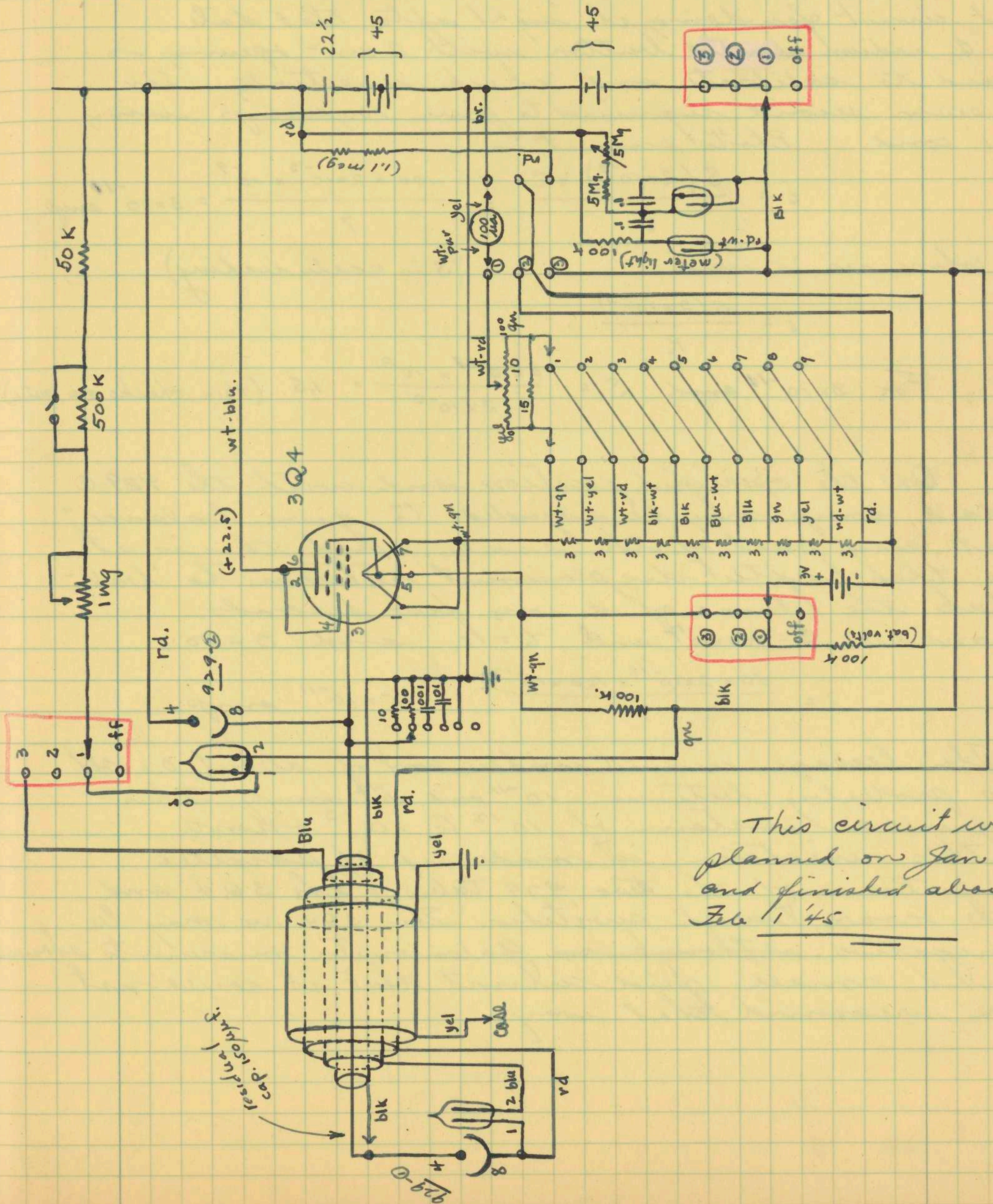
Jan 19 '45 Above ckt built and found reasonably good. Tried it out on a P-7 tube and decided to try a battery unit for Newton's photometer. The circuit now under way is the following.



meter should go to 2 circuit 3 position switch



March 3 '45 After experimenting with circuit for Edgerton. Sprague and I built a portable unit to be used by Newton.



This circuit was planned on Jan 17 1947 and finished about Feb 1 '45

When building was complete about Feb. 1 I took instrument over to Gen. R. to discuss features with M. Eastham. Suggestion to make meter light flicker at 1 second was made by Sinclair and I worked out circuit for doing it right after that date.

A radium excited button with 2 cm² opening is used to calibrate and check sensitivity. Six to seven second required to give 100 μamps using .001 cond. Photo current is

$$i = \frac{S(2\times10^{-3})\times C}{t} = \frac{100\times2\times10^{-3}\times10^{-9}}{7} = 3\times10^{-10}\ \text{amp.}$$

when res is used (S is scale reading)

$$i = \frac{S(2\times10^{-3})}{R}$$

For 3×10^{-10} and $S = \frac{3\times10^{-10}\times10^{8}}{2\times10^{-3}} = 1.5$ (this checks on meter)

On the open grid position and with the 929-① dark, comp. may be adjusted to give "balance" at any part of the scale. If this is at 50 then after displacement return to "bal-" take the time of a very few seconds. Consider $C = 150\times10^{-12}$ and $t = 1$ and $S = 50$

$$i = \frac{50\times2\times10^{-13}\times150\times10^{-12}}{1} = 1.5\times10^{-11}\ \text{amp.}$$

The leakage current under emf of about 0.1 volt is probably between 10^{-11} and 10^{-12} amp. This give a resistance of 10^{12} to 10^{13} ohms. This resistance is made up of parallel resistance of the ~~two~~ 929 tubes, the 3Q4 and the coax and switches. The 3Q4 res may be negative. ~~although so~~ Galvanometer measurements showed such small grid current that it could not be measured that way.

~~Abs spec solution 5:327~~

~~Density 1:154 3:43~~

~~Diel. const 6:77~~

~~Elec. cond. 6:149 :154~~

Grating Spacing 6:7

~~Heat of dission 5:418~~

~~Light transm 5:264~~

~~Melting pt 1:154~~

~~Photo el. current 6:69~~

~~Ref. index 1:154, 165. 7:13,14~~

~~X-ray diff data 1:345.~~