

24

P-50-62 1970 Ergometry



# COMPUTATION NOTE BOOK

43-648

Course

Ergometer ~~'66~~, Jan '67 Feb

Name

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10 Jan 67

An exercise device is needed for a planned space mission for prevention of deconditioning. A proposed bar bell like arrangement has been planned for "total body" exercise & regional conditioning. The contractor cannot



produce prototypes and agreed to rush thru a multi purpose test jig to be followed by fixed purpose arrangements. S.H.R.D. was given a small contract to produce the device below.

Existing ergometers depend upon some form of friction (mechanical) or an electrical generator which has unknown combinations of inertia and friction. It is obvious that the same varying combinations produce <sup>varying</sup> energy costs for example the Wilford Hall experience - the two ergometers. To look at an electrical ~~etc~~ analogy the generator is poorly matched by a resistive load.



The method of calibration, a measurement of force required to maintain a ~~slow~~ constant rate, sees only the resistive component.

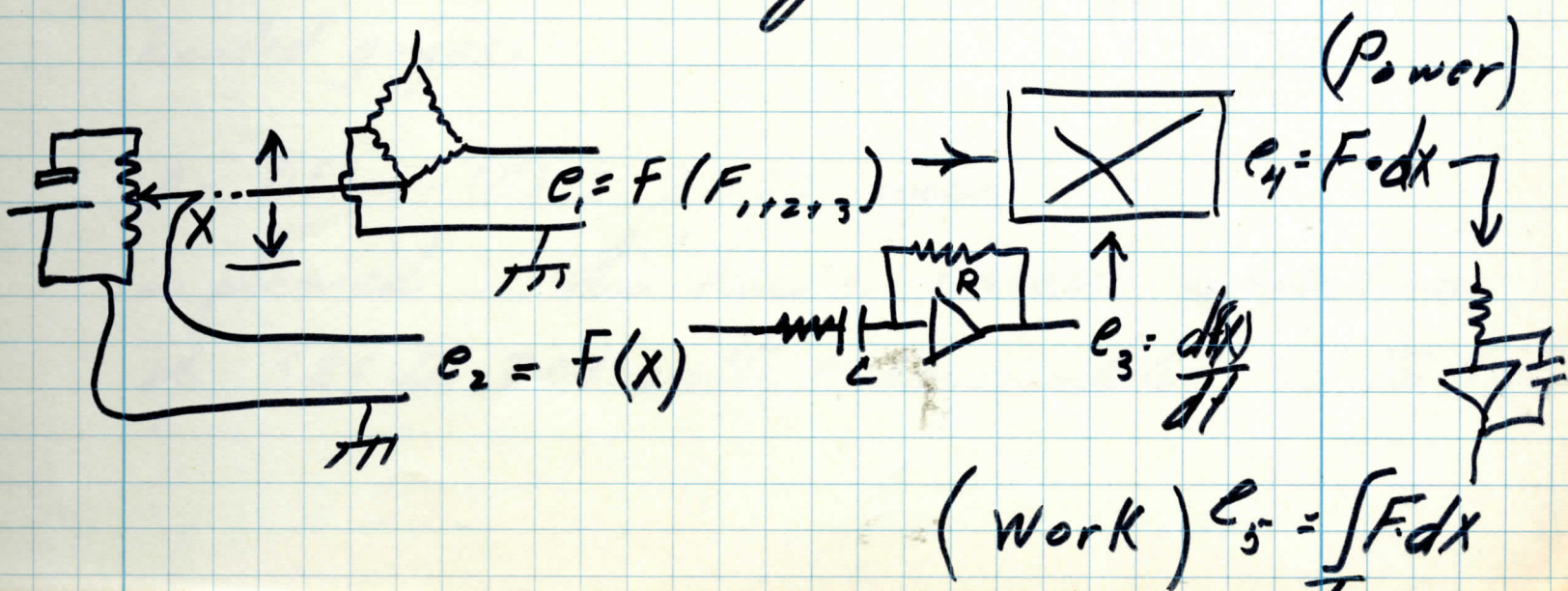
In this case we will attempt to provide at least three forces which the body is used to dealing -

$$1) F_1 = K_1 \quad (\text{eq. to gravity})$$

$$2) F_2 = K_2 \dot{x} \quad (\text{resistive})$$

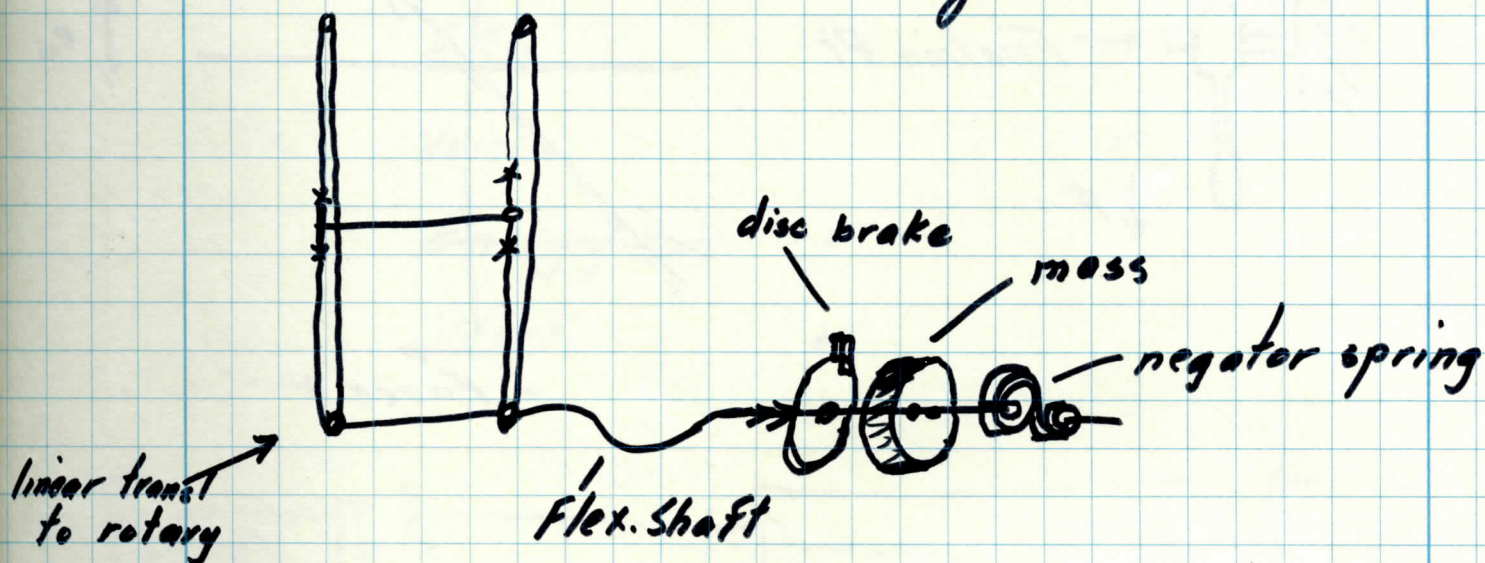
$$3) F_3 = K_3 \ddot{x} \quad (\text{inertial})$$

The second innovation is the measurement of energy and work at the point of input. This is possible since the mechanical system is unilateral i.e. it costs muscular energy to add or remove energy from an external mechanical system.



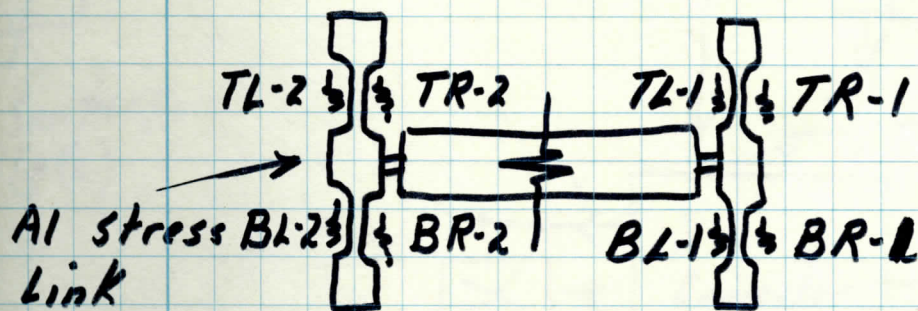


In addition the physiological effects must be determined probably by conventional  $O_2$  consumption techniques for contrast. The mechanical arrangement is below.



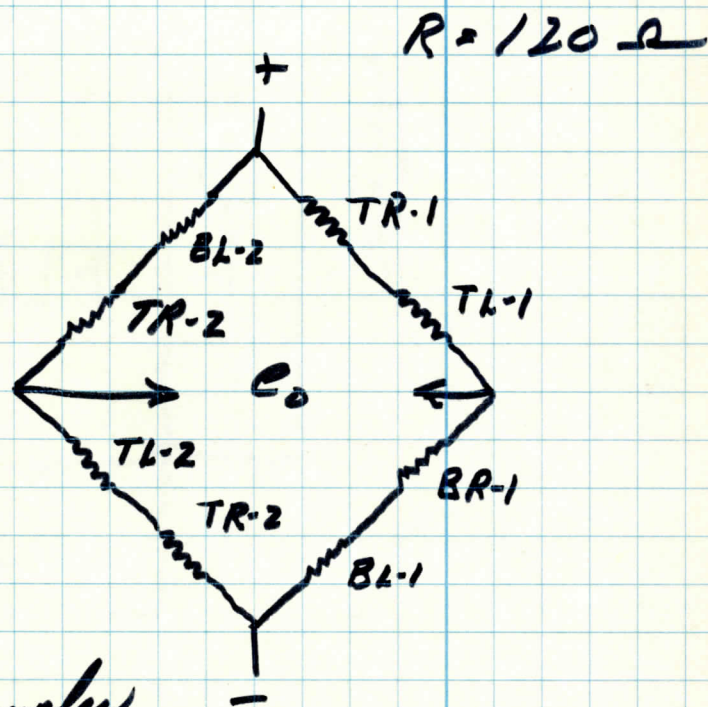
### Electrical Sensing -

$$\frac{1.5}{1.2 \times 10^2} = 1.25 \times 10^{-2}$$



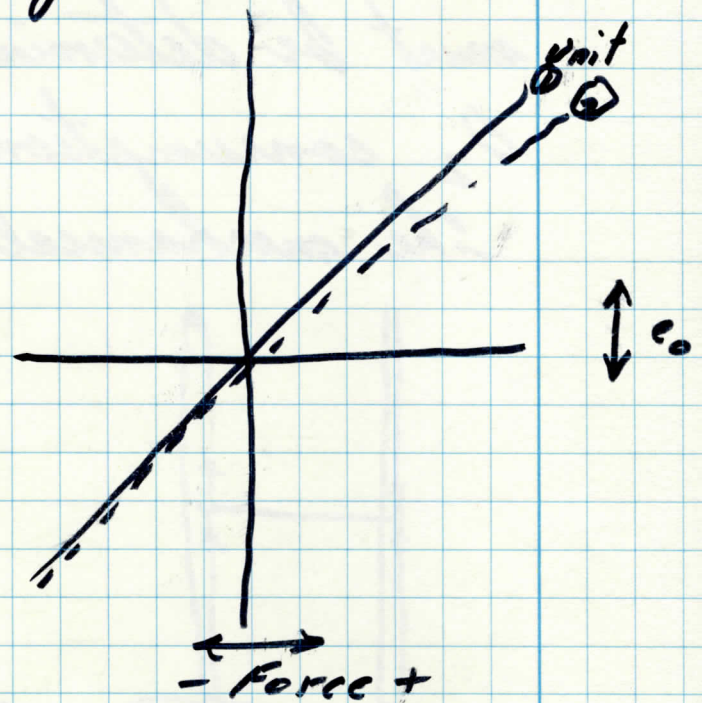
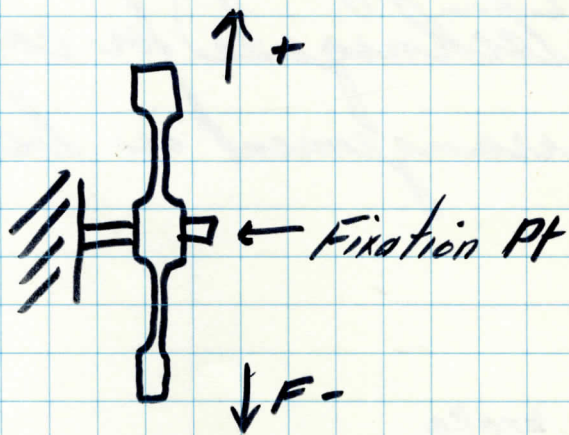
### Bonded gages.

An Offner (R)  $\approx 9803$  coupler is planned - this has a variable supply (sens.) of 5.85 to 3.04 volts & accommodates 90 to  $5 \times 10^3 \Omega$





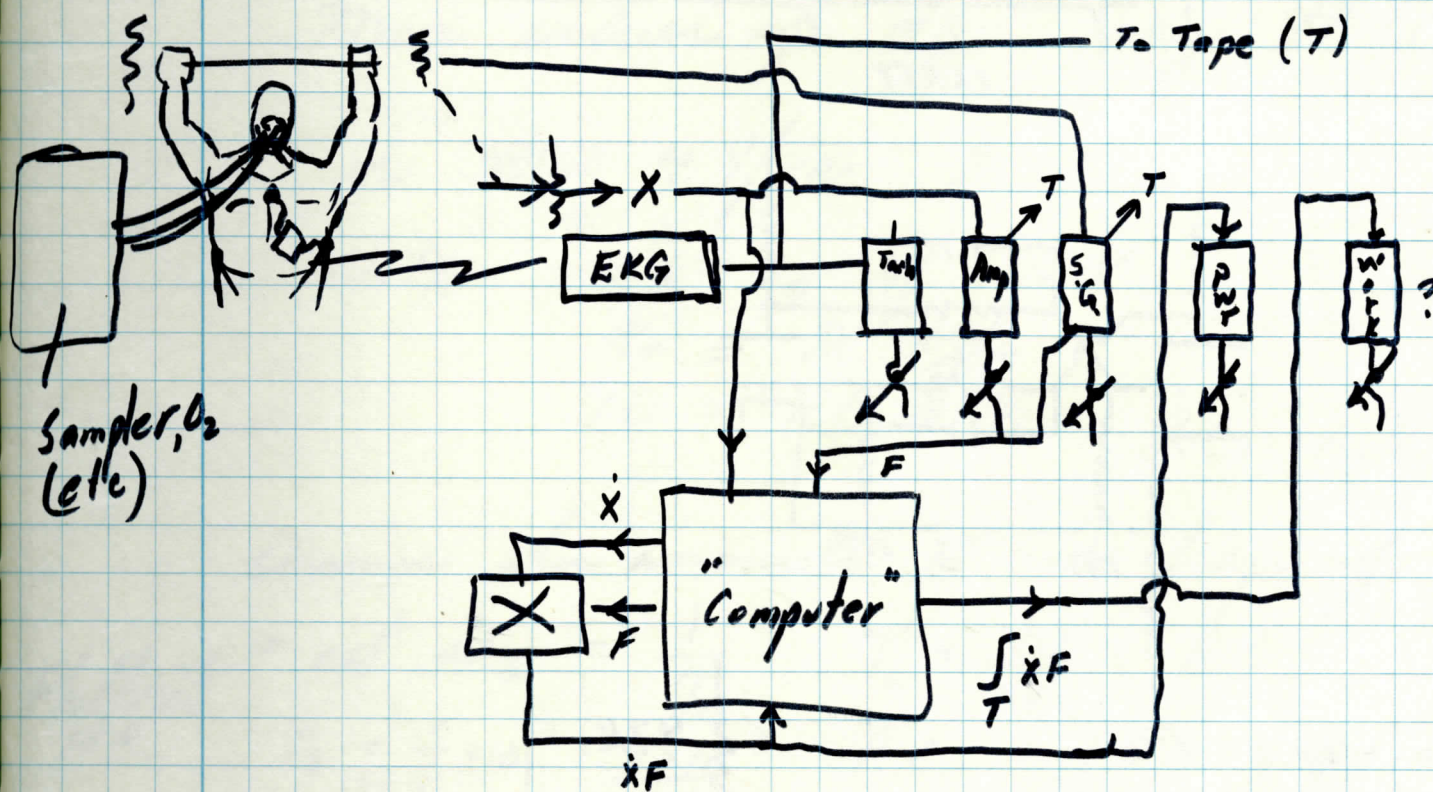
The stress links and gauges must be tested.  
Initial test:





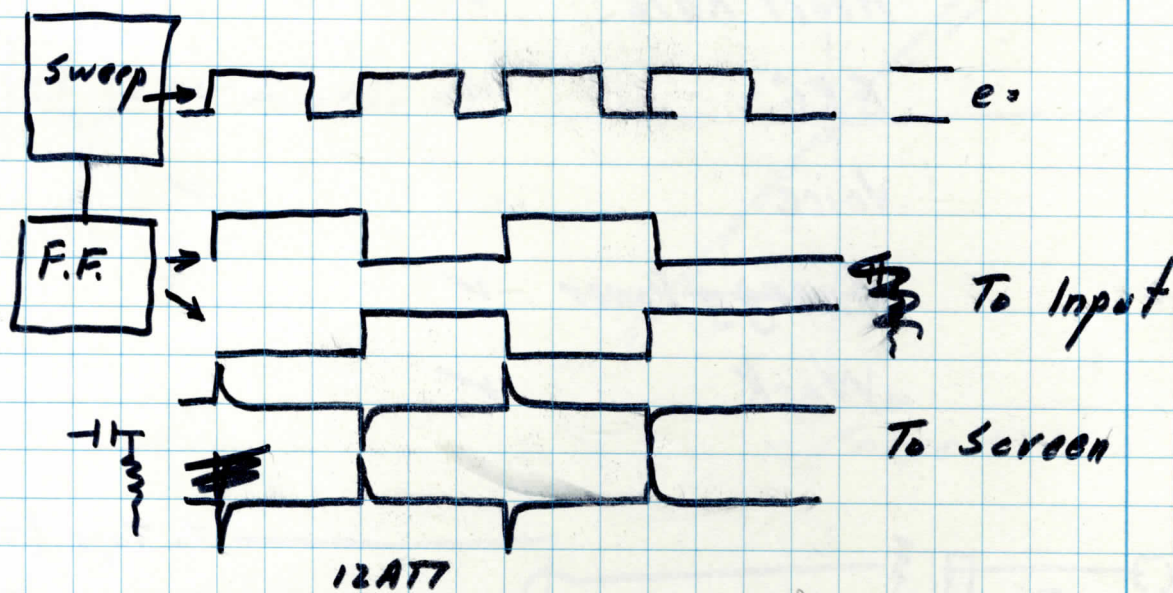
# Proposed inst.

|              | Graphic | Tape | Scope | Comment               |
|--------------|---------|------|-------|-----------------------|
| Force        | ✓       | ✓    |       |                       |
| X            | ✓       | ✓    |       |                       |
| Heart Rate   | ✓       |      |       |                       |
| EKG          |         | ✓    | ✓     |                       |
| Voice        |         | ✓    |       |                       |
| Energy Power | ✓       |      |       |                       |
| Work         | ✓       |      |       | Marker (?)<br>Pin (i) |

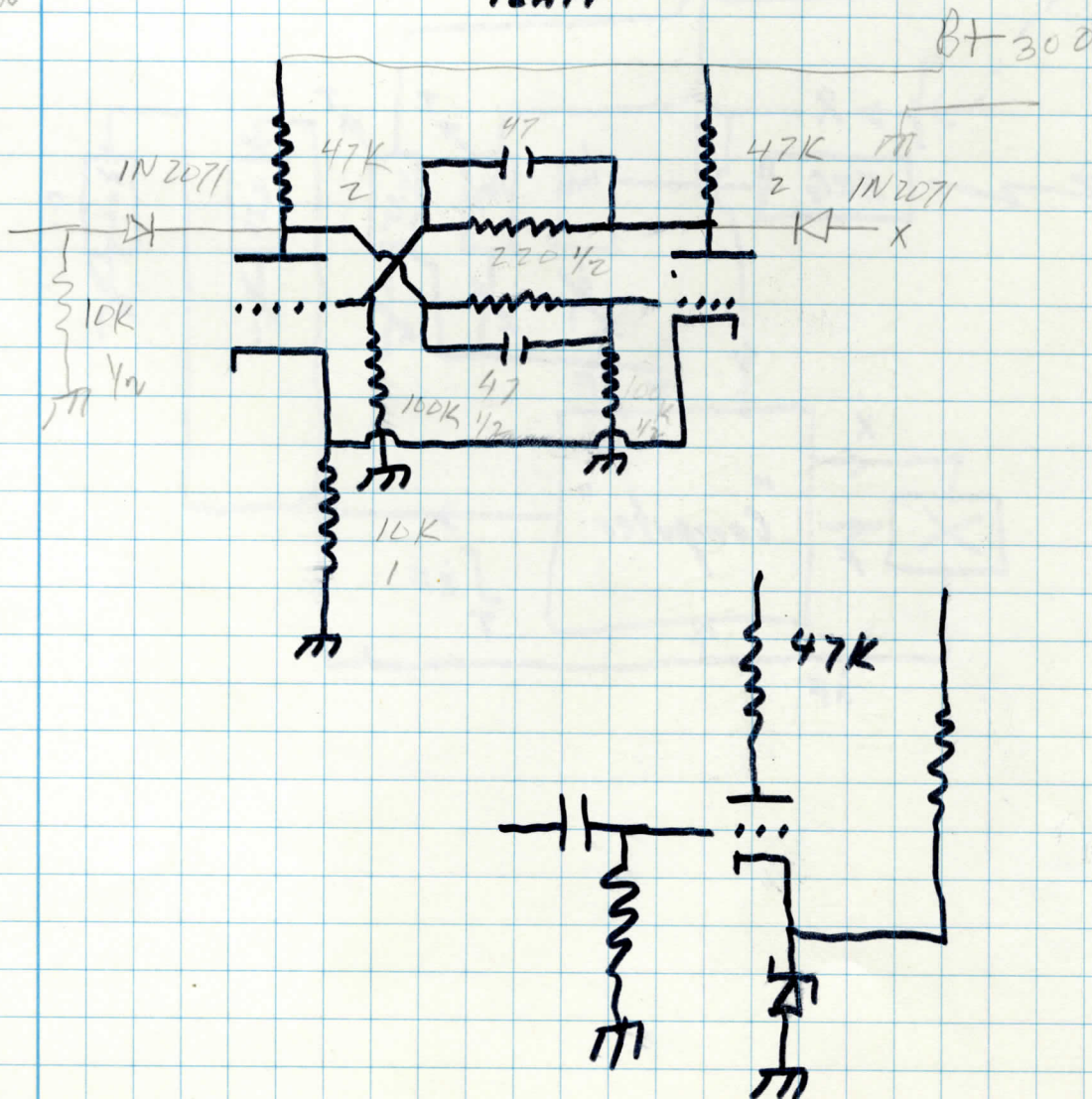




- \* split screen storage



$$\frac{3 \times 10^2}{5 \times 10^4} \approx \frac{1}{2} \times 10^{-2}$$





# Differentiator-

Minimum  $\frac{dX}{dt}$  values are needed to determine  
cator electrical values.

Input is  $\frac{e \text{ volts}}{X \text{ ft}}$  a max of  $\frac{15}{8}$  or  $\sim 2 \text{ V/ft.}$

Reduce this by half.  $1 \text{ V/ft.}$

Lowest value of  $5 \frac{\text{sec}}{\text{ft}}$  seems reasonable.  
or  $.2 \text{ V/sec.}$

Differential eq. is  $RC \frac{de}{dt} = e_0$

Max values of  $\frac{dX}{dt}$ : say  $4 \text{ ft/sec}$   
or  $4 \text{ V/sec.}$

With max  $e_0$  of  $10 \text{ V}$ :

$$e_0 = RC \frac{de}{dt}$$

$$10 = RC \cdot 4 \quad RC = 2.5$$

Assume this amounts to max freq. of  $5 \text{ CPS}$

Philbrick  
H.B.

$$\omega_c = \frac{1}{T_c} \quad T_c = \frac{1}{\omega_c} = RC$$

$$T_c = \frac{1}{5 \times 10^2} = \frac{2 \times 10^{-3}}{\pi} = R.C. = \frac{1 \times 10^6}{\pi \text{ meg}} \times \frac{1 \times 10^{-9}}{.001 \mu \text{f}}$$

$$T_c = \frac{1}{\omega_c \times 10^2} = \frac{1}{2\pi \cdot 5 \times 10^2} = \frac{1}{\pi} \times 10^{-3}$$



Calibration of strain gages -  
 Apr. as on P- & output of pre-amp  
 read on H.P. DVM.

| Voltage                  | Gage | Wt            |
|--------------------------|------|---------------|
| + .0419                  | 1B   | 6m            |
| + .0244                  | 1B   | 16895         |
| + <del>.0004</del> .0204 | 1B   | 9095          |
| + .0084                  | 1B   | 6495          |
| + .0029                  | 1B   | bucket = 2832 |
| + .0032                  | 1T   | 0             |
| - .0028                  | 1T   | 0             |
| - .0186                  | 1T   | bucket        |
| - .0360                  | 1T   | 9095          |
| - .0149                  | 1T   | 16895         |
|                          |      | 6495          |
| + .0036                  | 2B   | 0             |
| + .0089                  | 2B   | bucket        |
| + .0215                  | 2B   | 6495          |
| + .0242                  | 2B   | 9095          |
| + .0419                  | 2B   | 16895         |
| + .0038                  | 2T   | 0             |
| - .0026                  | 2T   | bucket        |
| - .0149                  | 2T   | 6495          |
| - .0183                  | 2T   | 9095          |
| - .0352                  | 2T   | 16895         |

Offset -  $\times 10 + .5 \text{ mV/cm}?$



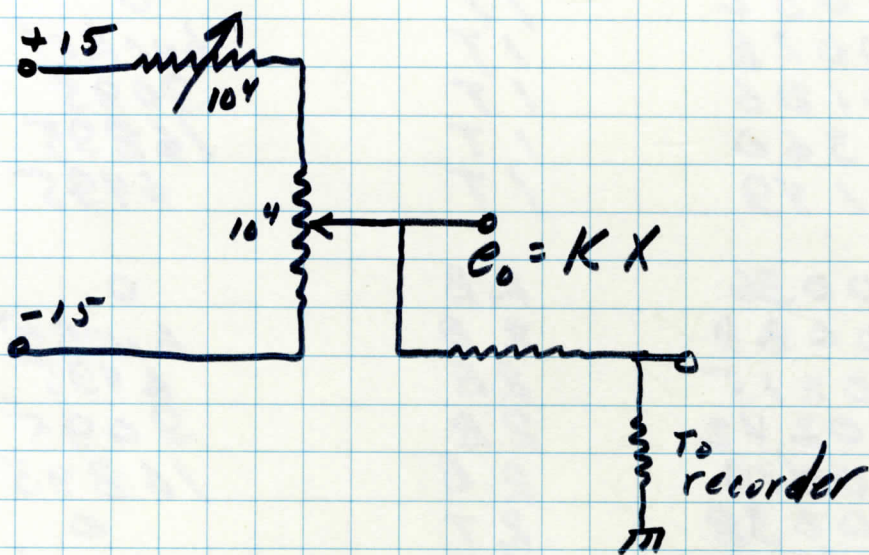
Displacement Pot (X)  $R = 10^4$

$$W = \frac{E^2}{R} \quad \& \quad E = \sqrt{\frac{WR}{1}} = \frac{.5 \times 10^4}{1} = .5 \times 10^2$$

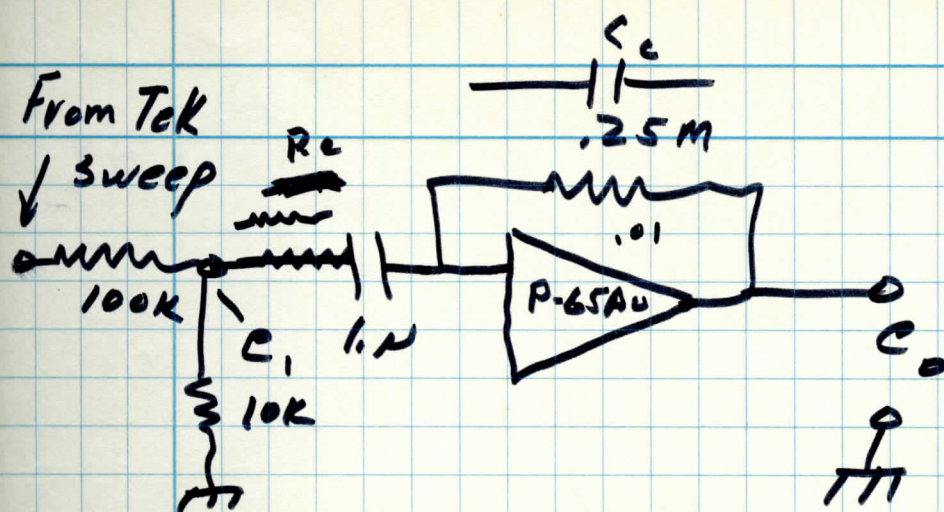
$$= \cancel{100} .708 \times 10^2 = 70.8 \text{ V}$$

$$I = \frac{E}{R} = \frac{30}{10^4} = 3 \text{ mA}$$

$$\text{Max load Current} = \frac{10}{2.5 \times 10^5} = 4 \times 10^{-5} = 40 \mu\text{A}$$







$$TC = .25 \times 10^6 \times 10^{-7} = \frac{F_0}{\frac{dF}{dt}}$$

T<sub>0</sub> HP DVM

$$e_1 = \frac{9V}{5 \text{ sec.}} = 1.8 \text{ V/sec.} - .5 \text{ sec/cm.}$$

Sweep  
speed  
cm. / sec

P<sub>0</sub>

Volts

e<sub>in</sub>  
V/sec

RC

|                     |                       |     |      |
|---------------------|-----------------------|-----|------|
| 1.                  | .220                  | .90 | .245 |
| 2.                  | .112                  | .45 | .249 |
| 5.                  | .048                  | .18 | .267 |
| e <sub>in</sub> = 0 | .006 (noise + offset) |     |      |
| .5                  | .430                  | 1.8 | .239 |
| .2                  | 1.07                  | 4.5 | .240 |
| .1                  | 2.13                  | 9.0 | .237 |
| .05                 | 4.26                  | 18. | .237 |

~.15 VPP noise - h.f.

added .02 cap C<sub>c</sub>

~.01 VPP noise

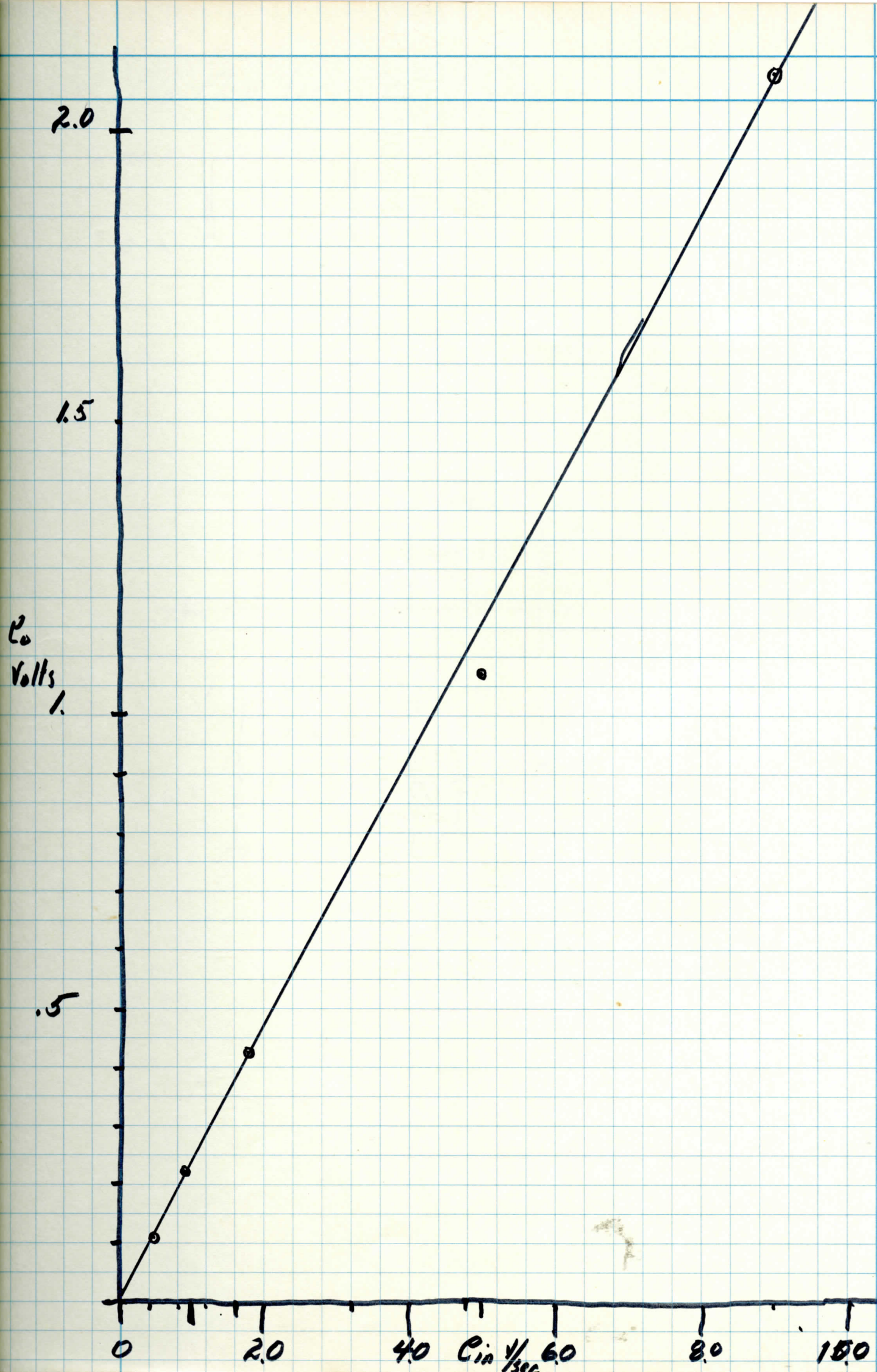
e<sub>in</sub> 0 — .0059 (noise + offset)

Max.  
Summing  
I

$$\frac{10}{2.5 \times 10^5} \\ 4 \times 10^{-5}$$

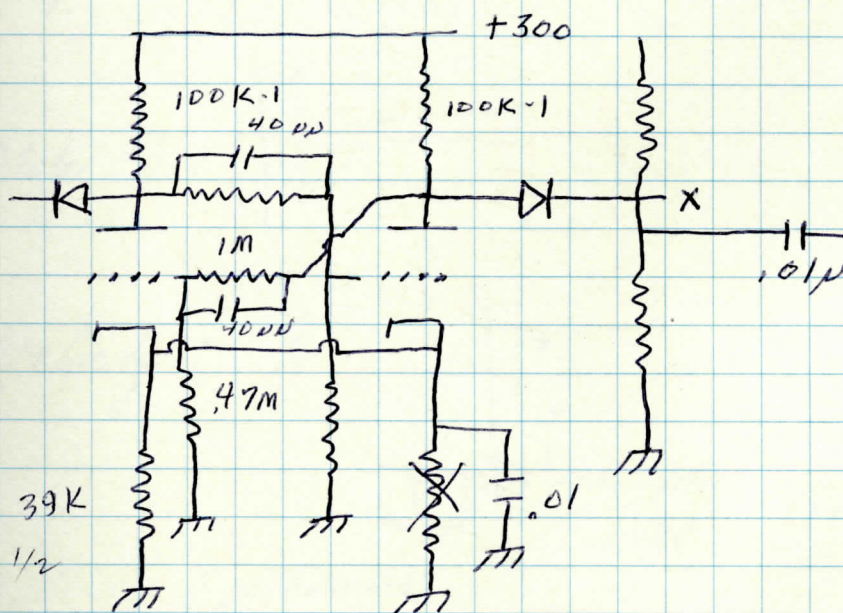
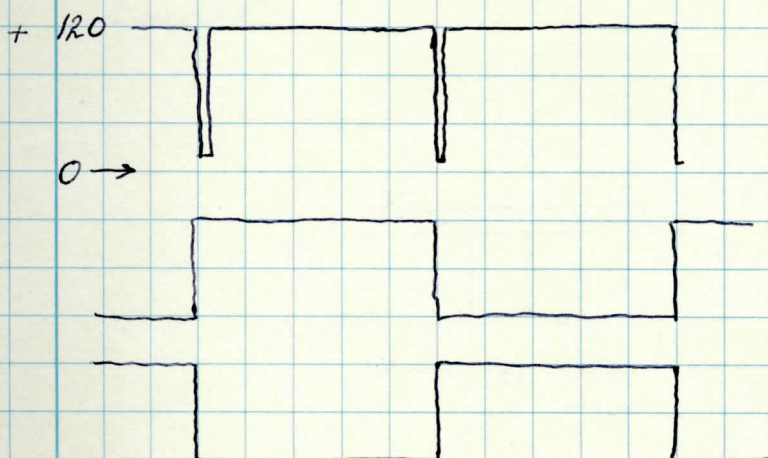
|     |       |
|-----|-------|
| 5   | .0479 |
| 2   | .112  |
| 1   | .219  |
| .5  | .432  |
| .2  | 1.07  |
| .1  | 2.13  |
| .05 | 4.26  |







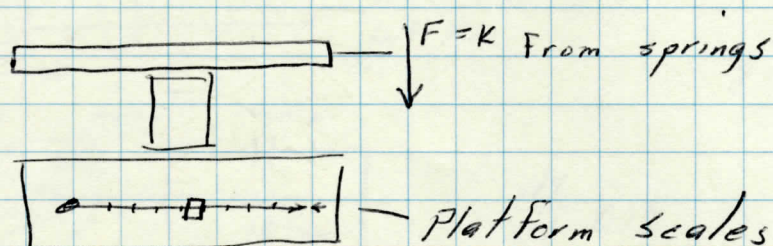
Flip Flop For EKG display on storage scope:



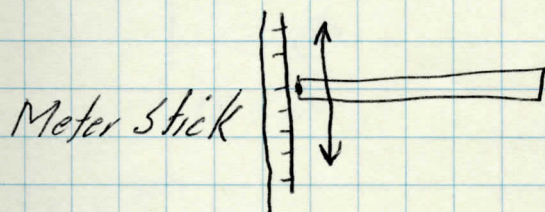


# Calibration of Ergometer

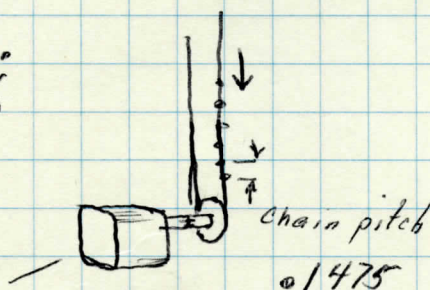
Force:  $F$



Displacement:  $x$



Velocity:  $\dot{x}$



$$\begin{array}{r} 0.1475 \\ \times 24 \\ \hline 3.5400 \end{array}$$

Synchronous  
Meter Coupled to take off shaft to drive at constant  $\omega$ .

$$1 \text{ rev.} = 3.54'' \text{ or cm.}$$

$$1 \text{ R/sec} = 3.54''/\text{sec} \text{ or } \sim 8.75 \text{ cm/sec}$$

← Mean Rate is 1'/sec.

30:1  
Shaft to  
Pot.

$$\begin{array}{r} 172.5 \text{ RPM} \\ \times 3.54 \text{ "/Rev} \\ \hline 6900 \end{array}$$

$$8625$$

$$5175$$

$$60 \frac{8625}{m} = 610.650$$

$$60$$

$$106$$

$$60$$

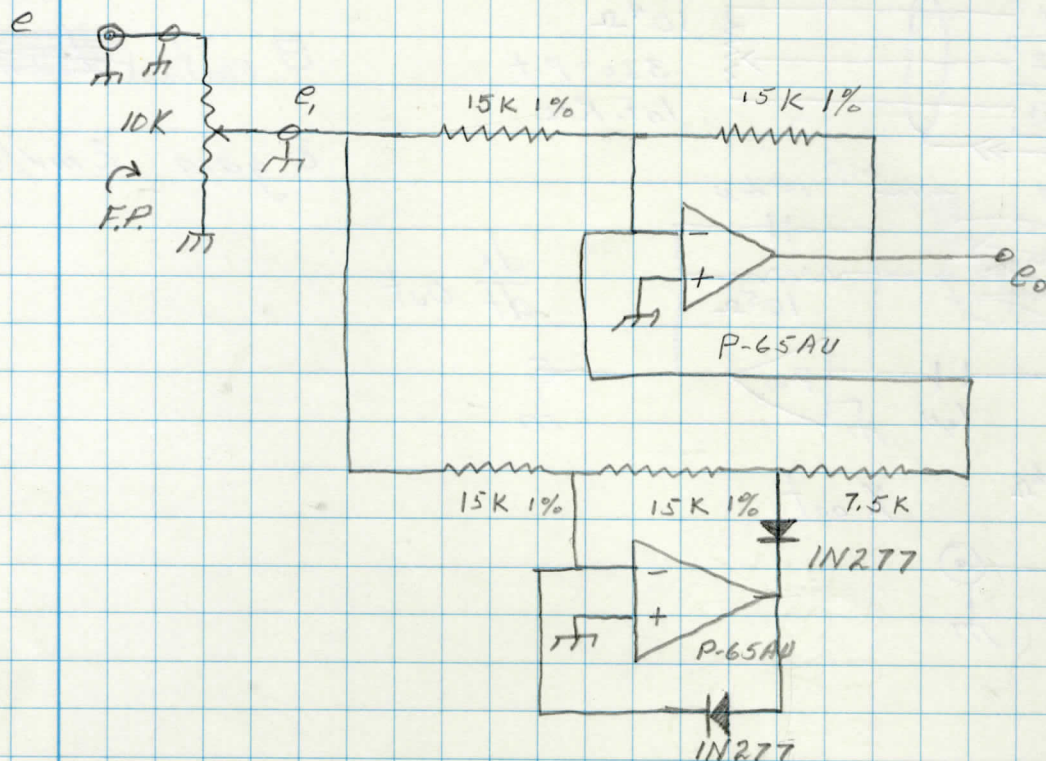
$$465$$

$$10.17''/\text{sec}$$

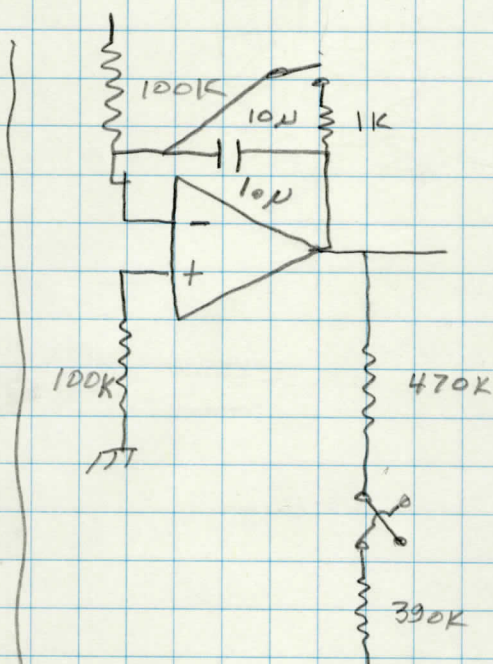
$$\cdot 848''/\text{sec}$$



Abs. Value Ckt. for Integ  
Force in any direction results in external  
work for the subj - hence need for ckt.



| $e_1$<br>Volts | $e_0$<br>Volts |
|----------------|----------------|
| +              | +              |
| 4.50           | 4.67           |
| 4.00           | 4.14           |
| 3.00           | 3.10           |
| 2.00           | 2.06           |
| 1.00           | 1.02           |
| .500           | .496           |
| .250           | .238           |
| .101           | .085           |
| .088           | .032           |
| .000           | .000           |
| .000           | .000           |
| -.050          | .045           |
| .100           | .095           |
| .250           | .246           |
| .500           | .498           |
| 4.50           | 4.54           |





26 Jan. Calibration of Instrumentation

Record ①

or  
27

Force is calib. by allowing spring loaded bar to rest on gravimetric balance

Velocity is determined by attaching a constant  $\omega$  ( $\frac{1725}{10}$  RPM) motor + recording dX.

Abs. value, multiplier and integ. ckt's are calib. by placing fixed values of resistance across different. cap. & one end conn. to 15 V. supply.

Computer + recorder circuitry were ~~tested~~ <sup>inspected</sup> for ~~accuracy~~ <sup>linearity</sup> by moving the bar over the same displacement at different rates & a ~~same~~ fixed load.

Record ①

|                       | Rate 1 1/2 | Defl (mm)  | Rate 2 1/2 | Defl (mm) |
|-----------------------|------------|------------|------------|-----------|
| 20# Spring Only       | ~ 4        | 12.5 (12*) | ~ 8        | 11 (11*)  |
| 20# " + 20# Inertia - | ~ 4        | 12.5 (12*) | ~ 8        | 12. (11*) |

\*  
Record ②

28 Jan. Runs  $\bar{S}$   $O_2$  uptake + rate measurements.  $\frac{40 \text{ mm defl.}}{7'} = 5.72 \frac{\text{mm}}{\text{ft}}$   
Displacement - Total = 2.1 M or  $\frac{2.1}{.365} \approx 7'$

Velocity - meas. from record  $\frac{I'}{8 \text{ sec.}} = .875'/\text{sec}$  (Calc. from geom. is .848'/sec.)

Arg. values  $\frac{.86'/\text{sec.}}{2.5 \text{ mm.}} = .344'/\text{s/mm.}$

Elec. - 3.5 mm. x ~~3.5~~  $.344'/\text{s/mm} = 1.202'/\text{s}$

Force - 20# (from springs only) / 5.5 mm = 3.64 #/mm.

Power - 20# x 1.2' / s =  $\frac{24.16 \text{ Ft./Sec.}}{1.3 \text{ mm.}} = 18.4' \text{ #/s/mm.}$

Work - 15 s. x 18.4' #/s = 275 Ft # / 10 mm. = 27.5 Ft # mm.

Cont. on  
bottom of  
next pg.



Vol in:

$$V_{N_2} + V_{O_2} + V_{\text{misc}} \\ \text{SS} \\ 0$$

$$\text{Vol out: } V_{N_2} + V_{CO_2} + V_{O_2} + V_{H_2O}$$

O<sub>2</sub> consumption instrumentation:

A Beckman E-2 ? paramagnetic O<sub>2</sub> device  
 & slidepack readout (null balance) & a Beckman Leston  
 CO<sub>2</sub> meter are in series & a pump preceded by a  
 drying tube. A ~~new~~ set of std. gases will be used for  
 comparison. Nose clip & small expiration valve held by  
 a mouth piece are connected thru 1/4 inch flex tubing  
 to a Tissot (Collins). Gases will be sampled from this  
 directly.

28 Jan ② contd.

1<sup>st</sup> Run - 20 # springs (F=K) only - unpaced ( $\frac{7N}{251s} = 3.575/N$ )

Power peak 20 mm x 18.4 #/mm = 368.

Avg. Slope of integ 25 mm/10 sec =  $\frac{25 \text{ mm} \cdot 27.5 \text{ #/mm}}{103} : \frac{687 \text{ #}}{10 \text{ sec}} = 68.7 \text{ #/s}$

Work/cycle - Up - 6 mm x 27.5 #/mm = 165.0 # Down - 2.6 mm x 27.5 #/mm = 64.8 #

On this run the multiplier was overdriven -

2<sup>nd</sup> Run - 20 # F=K + 20 # F=MA

Peak ~~Power~~ Power 21 mm

Avg. Slope same as 1<sup>st</sup> Run

Difference in shape of power curve -

3<sup>rd</sup> Run - Short run as above -

paced 43/N { 4<sup>th</sup> & 5<sup>th</sup> as above & gain ÷ on input to 1 leg of mult  
 6<sup>th</sup> Run Added Resistance for Avg Value of  $368 \text{ #/mm} \times 75 \text{ mm} = 27.3 \text{ #}$   
 Avg Pwr -  $2 \times 35 \text{ mm} \times 27.5 \text{ #/mm} / 30 \text{ sec} = 1925 \text{ #/30} = 64.2 \text{ #/s}$   
 7<sup>th</sup> As above + inert  $2 \times 20 \text{ mm} \times 27.5 \text{ #/mm} / 15 = 26.7 \times 2 = 53.4 \text{ #/s}$



BP - Brass scale correction factor

25

Vol Expired air - Corrected STPD

% CO<sub>2</sub> expired air

- Consolazio-Johnson-Pecora

% O<sub>2</sub> expired air

Measurements of Metabolic Function  
in Man

$$\dot{V}_{O_2}(L) = Vol_{STPD} \times (\% N_{2exp} \times .265 - \% O_{2exp air})$$

$$\frac{l}{kg} = cc/kg/TBW/min$$

$$\frac{18.4}{550 \times 10^{-2}} = 3.345 \times 10^{-2}$$

$$\frac{273 + T^{\circ}C}{273} \cdot \frac{BP + 760}{BP} \cdot 9$$



Sat. 28 Jan

Calibrated + ran tests (W.T.) - All inst.

worked well except  $O_2$  drifted - Quiddiegs rose!

Records

1

+

2

1<sup>st</sup> Run

30 Jan -

30 # - 3

Tread Mill

3

Taylor - 83.51 L/M

120.8

16.64  $O_2$ 4.46  $CO_2$ CO 30.5~~7~~66 L/M (38.3%) 4.628 L/M (49.6%  $Ky/M$ )

RQ 1.04

1.18

HR 173?

178

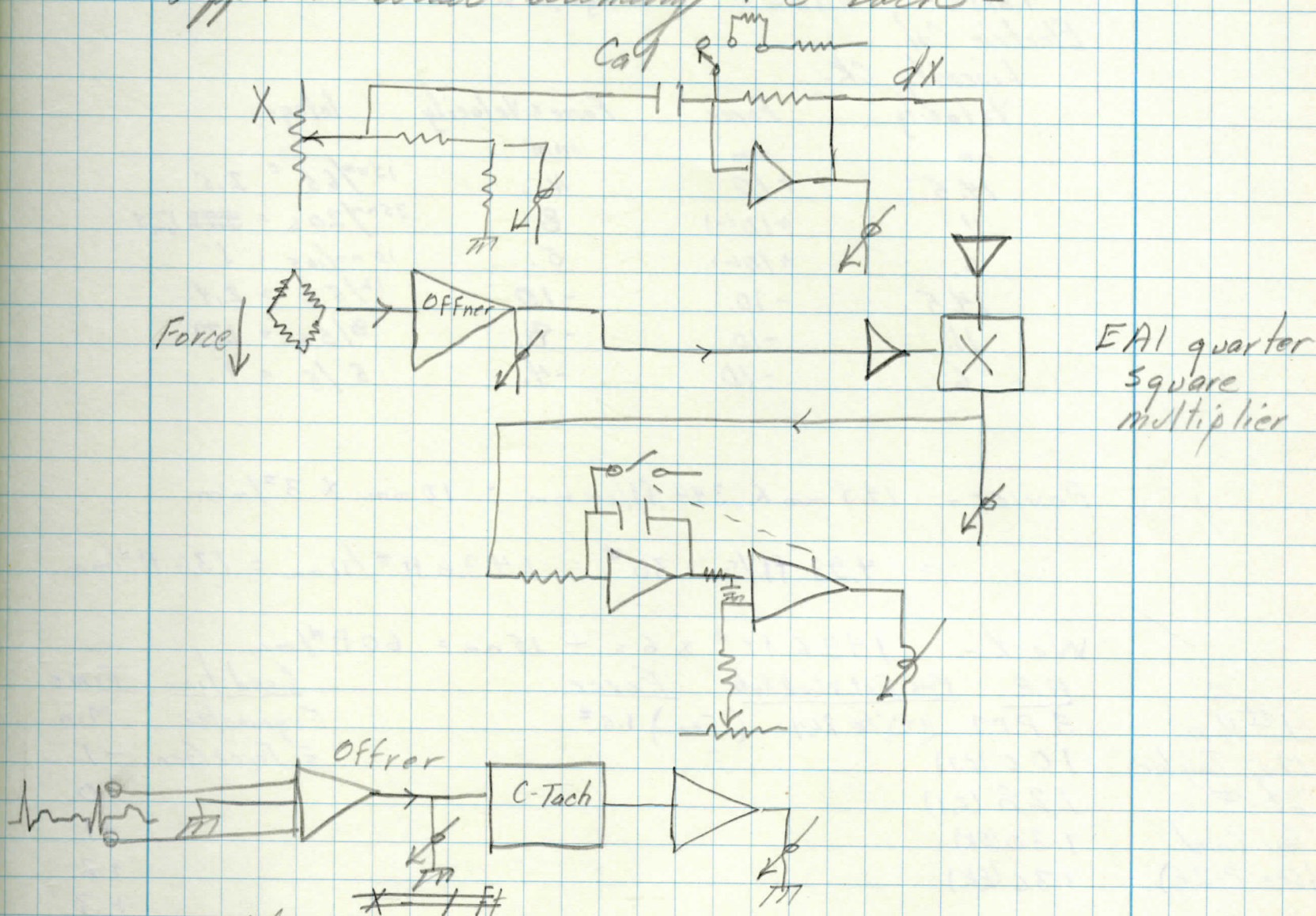
T.V. 83'

120.8



Mon. 30 Jan.

Modified instrumentation by adding elec. calib. to diff. + wired telemetry & C tach -



Calib:  $dX$  1 Ft. sec. (meas. from record) = 3.5 mm for .917 1/sec

$$X = \frac{2.1 M}{3.05 M Ft.} = 6.78 Ft. \quad dX = \frac{6.78 Ft.}{7.4 sec} = .917 1/sec$$

$$\alpha \quad 1 mm = .2462 1/sec/mm -$$

Check of multiplier & abs. value ckt.



Maj. Taylor 205# 30 Jan

Calib.  $X = \frac{7'}{40 \text{ mm}} = .175' / \text{mm}$

$X = \frac{.864}{2.5 \text{ mm}} = .344' / \text{mm}$

Force =  $\frac{15 \text{ kg}}{11 \text{ mm}} = 1.36 \text{ Kg/mm} \approx 3\# / \text{mm}$

Electric Cal.

Linearity CK.

| Velocity<br>mm | Force<br>mm | Force x Velocity<br>mm | Integ-                                              |
|----------------|-------------|------------------------|-----------------------------------------------------|
| 14.5           | +10         | 11                     | $15 \text{ mm} / 6 \text{ s} = 2.5$                 |
| 11.            | +10(-)      | 8                      | $35 \text{ mm} / 20 \text{ s} = \cancel{3.72} 1.75$ |
| 6.             | +10(-)      | 5.                     | $10 \text{ mm} / 10 \text{ s} = 1$                  |
| 14.5           | -10.        | -10.                   | $12 / 5 \text{ s} = 2.4$                            |
| 11.            | -10.        | -8.                    | $9 / 5 \text{ s} = 1.79$                            |
| 6.             | -10         | -4.                    | $5 / 5 = 1.$                                        |

Power -  $14.5 \text{ mm} \times .344 \text{ ft/sec mm} \cdot 10 \text{ mm} \times 3\# / \text{mm}$

$= 4.99 \text{ ft./s.} \cdot 30\# = 149.6 \text{ ft.}\# / 11 \text{ mm.} = 13.6 \text{ ft}\# / \text{mm.}$

Work -  $149.6 \text{ ft}\# \times 6 \text{ s} \div 15 \text{ mm} = 60 \text{ ft}\# / \text{mm}$

1<sup>st</sup> Run  
Maj. Taylor  
205#  
Fair Cond.  
(see P-26)

H.R. Max. Ext. Work Rate Force  
BPM (1.5 mm)' / # 20.4 (5+mm) 1.5#

100 (C.T.)

128 (C.T.)

130 (EK)

136 (EK)

Condition Time

Ergometer Min

5 Force Gen -1.

0

+1.

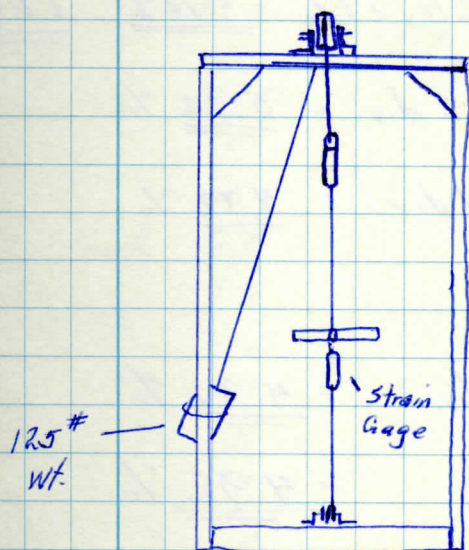
+2

+3.



7 Jan. 67

Runs - "Exergenie"



The strain gage & X pot were fed into the computer - The exergenie is an extremely variable device whose force varies <sup>total</sup> force temp & more cable factors -



7. <sup>Feb.</sup> Jan. - Exergenic - CO<sub>2</sub> prod.

Maj. Taylor -  
1<sup>st</sup> Run -

$$7.05 - 5.02 = 20.5 \text{ div} - \text{Subj. } 5.02 \% \text{ CO}_2 + 1 \text{ div} = \underline{\underline{5.12 \%}}$$

CO<sub>2</sub>

$$2^{\text{nd}} \text{ Run } 2.03 \% = 20 \text{ div} \text{ Subj. } 5.02 + 2 \text{ div} = \underline{\underline{5.22 \%}}$$

$$3^{\text{rd}} \text{ " } 2.03 = 20 \text{ div} - \text{Subj. } 5.02 - 1 \text{ div} = \underline{\underline{4.92 \%}}$$

Cooper -

1<sup>st</sup> Run

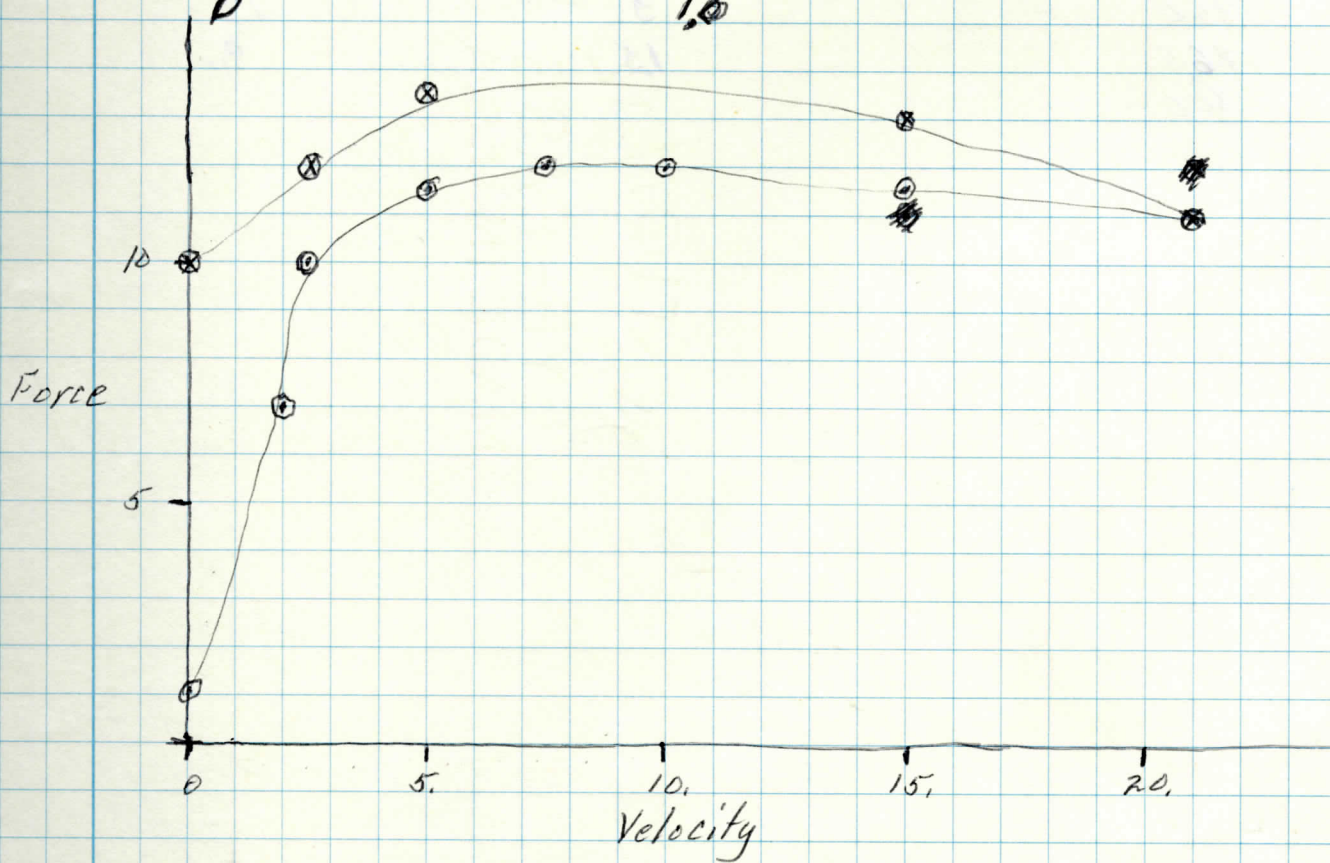
$$2.03 = 20 \text{ div} \text{ Subj. } 5.02 - 1 \text{ div} = \underline{\underline{4.92 \%}}$$

$$2^{\text{nd}} \text{ Run " " " " " " } = \underline{\underline{4.92 \%}}$$



15 Feb. Calc. of exergetic forces as  $F(X)$

| $\dot{X}$ | Force                    |
|-----------|--------------------------|
| mm defl.  | mm. defl                 |
| 0         | ← initial movement + 10. |
| 2.5       | 12.                      |
| 5.        | 13.5                     |
| 15        | 13.                      |
| Peak 21   | 11.                      |
| 15        | 11.5                     |
| 10        | 12                       |
| 7.5       | 12                       |
| 5         | 11.5                     |
| 2.5       | 10.                      |
| 2         | 7.                       |
| 0         | 10                       |





15 Feb-  $\dot{X}$  & Force vs  $F(X)$  Hix on Exer G.

| $\dot{X}$<br>5 mm = 1'<br>mm defl. | ft. | $\dot{X}$<br>mm defl. | Force<br>mm defl. | Power<br>mm. defl. |
|------------------------------------|-----|-----------------------|-------------------|--------------------|
| 0                                  |     | 0                     | 0                 | 0                  |
| 0                                  |     | start of 0 movement   | 10.               | 0                  |
| 2.5                                |     | 7.5                   | 15.               | 7.5                |
| 5.                                 |     | 12.                   | 13.               | 13.                |
| 7.5                                |     | 17                    | 12.5              | 16                 |
| 10.                                |     | 18                    | 12.               | 16                 |
| 12.5                               |     | 20                    | 11.               | 17                 |
| 15.0                               |     | 22                    | 11.5              | 18.5               |
| 17.5                               |     | 20                    | 12                | 18.                |
| 20.0                               |     | 17.5                  | 11.5              | 14.5               |
| 22.5                               |     | 12.                   | 11.5              | 10.                |
| 25.0                               |     | 9.                    | 12.               | 8.                 |
| 28.5                               |     | 1.5                   | 8.                | .5                 |
| 30.0                               |     |                       |                   |                    |



8 Feb. '67

The "exergenie" was fitted w a longer, in total, hand grip w rotating handles. Ng was run on this w Stalker, one of the best runners who had lifted weights in ~~college~~ high school (143<sup>#</sup>) made three runs on the TBE w a max of 30<sup>#</sup> w 30<sup>#</sup> inert.



17 Feb. '67 - see P-36

25. J

Force  
Velocity  
Power

⊙  
⊗  
⊕

20.

15.

10.

5.

0

0

5

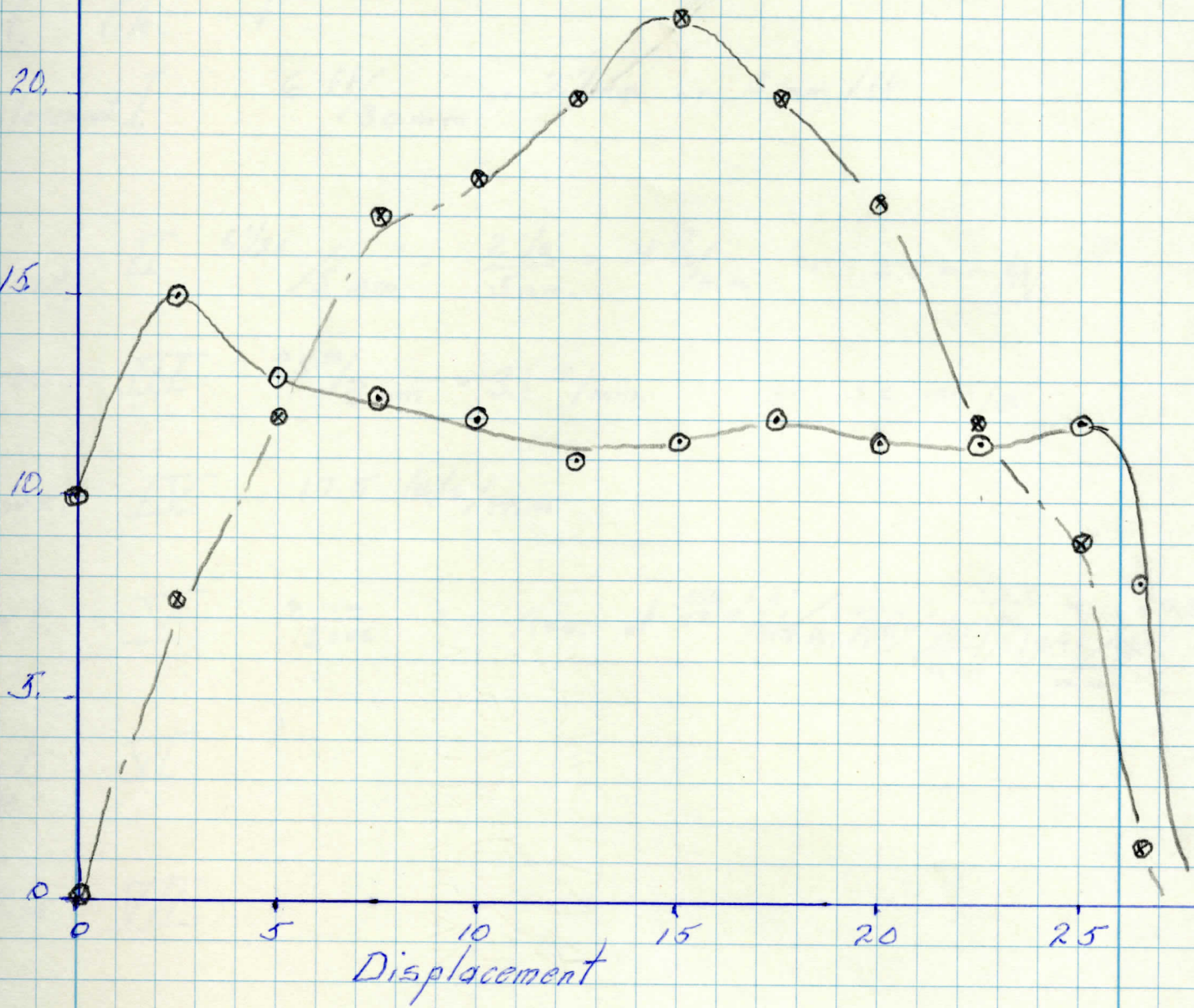
10

15

20

25

Displacement





# Reduction - Whalen - 9. Feb.

## Exergenie -

Funct. Ch. f

X Displacement I  $6 \text{ ft} / 30 \text{ mm}$  or  $.2 / \text{mm}$  or  $5 \text{ mm} / \text{ft}$

X Velocity II  $6^{1/3} / 5 \text{ mm} = \frac{2^{1/3}}{5 \text{ mm}} = .4^{1/3} / \text{mm}$  or  $2.5 \text{ mm} / \text{ft}^{1/3}$

Force III  $25 \# / 8 \text{ mm} = 3.1 \# / \text{mm}$  or  $.32 \text{ mm} / \#$

Power IV  $17.5 \text{ 'ft} / \text{s} / \text{mm}$

Work V  $\frac{6 \text{ mm}}{3 \text{ sec}} = 2 \text{ mm} / \text{sec}$  at  $\frac{149 \times 3 \text{ s}}{1 \text{ mm}} = \frac{447}{6} = 70.8 \text{ 'ft} / \text{mm}$

Heart Rate VI

EKG VII

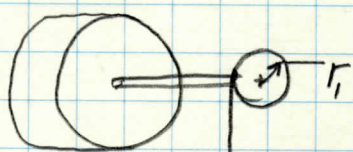


22 July '70

Equivalent moment of inertia of bicycle:

$$\underline{I = \sum M r^2}$$

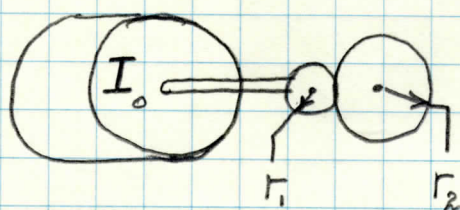
and for equivalent linear mass:

 $I$  = moment of inertia $M$  = Mass $r$  = radius $\alpha$  = rot. acc.

$$M_{eq} = \frac{I}{r^2}$$

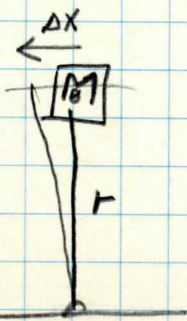
$$F = M_{equiv} A$$

and for gear ratios:



$$N = \frac{r_2}{r_1}$$

$$I_{eq} = I_0 = \frac{T}{\alpha} = \frac{NT}{\frac{\alpha}{N}} = N^2 \frac{T}{\alpha} = N^2 I_0$$

now for massless bike; assume  $M$  is at rear axle:

a small forward translation is equiv. to a C.C.W. rotation of the wheel &amp; mass at its periphery

$$I = M r^2$$



bicycle, contd.

for a typical case:

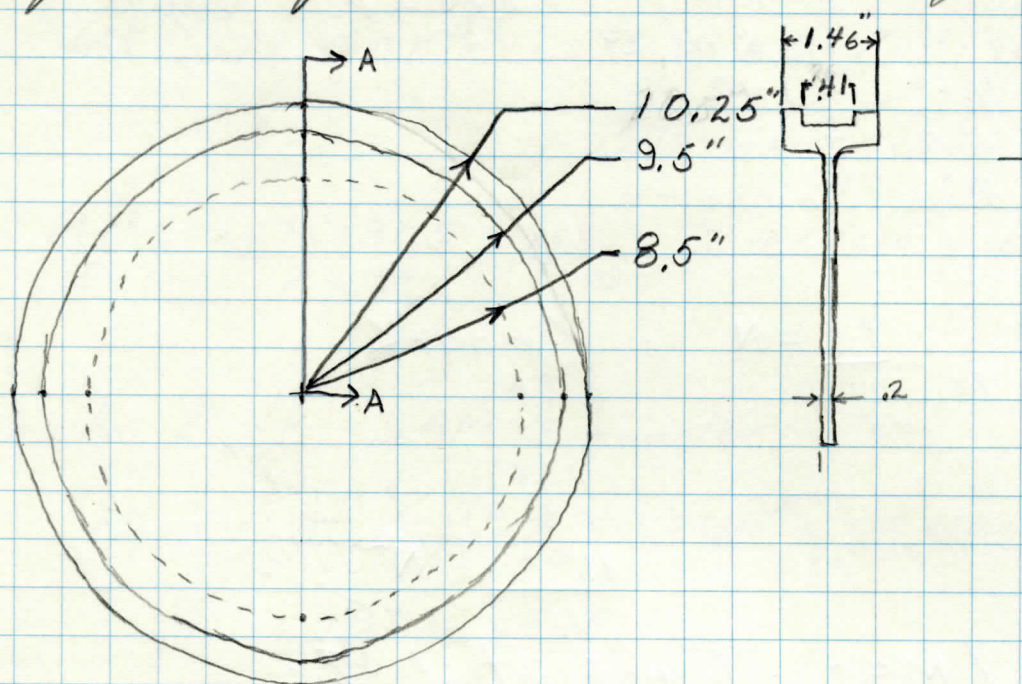
$$M = 150 \text{ #} / 32 \text{ '}/\text{sec}^2 \quad r = 1 \text{ ft.}$$

$$I_o = 150/32 \times 1^2 \approx 4.7 \text{ slug} \cdot \text{ft}^2$$

$$I_{eq} = 4.7 \text{ N} = 4.7 \times 3 = 14.1 \quad " \quad "$$



23 July '70 Modification of Monark ergometer



$I$  of segments:

Al. wt/cu.in.

Material removed. Mass = Vol.  $\times$  Dens.

①

.0975

Vol.  $\approx W \times L \times H \sim W \times \text{mean periphery} \times H$

?

$$\approx 1.5 \times 9 \times 2\pi \times 1 = 13.5 \times 6.28 = 84.8 \times 10^{-2} \text{ cu.in.}$$

177.5

$$\begin{aligned} I &= \frac{M(r_1^2 + r_2^2)}{2} = \frac{\text{Vol} \cdot \text{Dens} (r_1^2 + r_2^2)}{2 \cdot \text{Acc. in.}} = \frac{85 \times 10^{-2} (8.5^2 + 9.5^2) 9.75 \times 10^{-2}}{32 \times 2} = \frac{85 \times (72.5 + 105) \times 10^{-2}}{64} \\ &= 1.33 \times 1.77 \times 10^{-2} \times 9.75 \times 10^{-2} = 2.36 \times 9.75 \\ &= 2.3. \text{ slug ins}^2 \approx \underline{.16 \text{ slug ft}^2} \end{aligned}$$

Mass of rim. (treat as thin hoop)

$$\begin{aligned} \text{Vol} &\approx 2\pi r \text{ tw-groove vol.} = 2\pi ([9.87 \times .75 \times 1.46] - [41 \times .2 \times 9.87]) \\ &= 6.28 \cdot 9.87 (1.09 - .08) = 62. \times 1.01 \approx 62.06 \text{ in}^3 \end{aligned}$$

$$\text{Wt} = 62.06 \times 9.75 \times 10^{-1} = 6.08 \# \text{ Mass } \frac{6.08}{32} = .194 \text{ slugs}$$

$$I = MR^2 = .194 \times (9.87)^2 = .194 \cdot 97.8 = 19.2 \text{ sl/in}^2 = \underline{.133 \text{ sl. ft}^2}$$



slug, ft.

$$\text{Collins } 2 - 20 \# \text{ ft}^2 = .0625 - .625 \text{ slug ft}^2$$

$$\text{MSC} - 1.48$$

$$\text{"} - 1.2$$

Bill Young -

$$\begin{array}{r} 3.4 = N \text{ of Monark} \\ 15 \overline{) 51.} \\ \underline{45} \end{array}$$

$$\begin{array}{r} 3.4 \\ \underline{3.4} \\ 136 \\ \underline{102} \\ 11.66 = N^2 \end{array}$$

29 Mar. TO / MSC calc. &amp; exp. det. of I:

Doubt. figs. obtained by MSC (Anne Wilkinson)

Calculated on MSC is while meas. is

Measured technique is hanging known mass on arm & allowing it to fall & then measured  $\alpha$ . Did not allow for; resistance, change in effective moment arm,



## Monark Ergometer, cont'd.

$$\text{Mass, disk; } 50 \pi r^2 t = .2 \times 9.75 \times 10^{-2} \times 3.14 \times 9.5^2 = 90.5 \times 9.75 \times 3.14 \times .2$$

$$= 2.275 \times 10^3 \times 10^{-2} = 27.5 \times .2 = \underline{5.50} \# = \underline{.176 \text{ sl}}$$

$$I = \frac{Mr^2}{2} = \frac{.176 \times 90.5}{2 \times 144} = \frac{15.9}{2.88 \times 10^2} = 4.59 \times 10^{-2} = .04 \text{ slug. ft}^2$$

.4

Estimate I of SAM ergometer:

$$\text{Mass} = \frac{\pi r^2 t}{32} = \frac{9.75 \times 10^{-2} \times 3.14 \times 1.44 \times 4.16 \times 10^{-1} \times 10^2}{32}$$

$$= \frac{18.7}{32} = \underline{.585}$$

$$\text{Estimate I of lead: } I = \frac{.585}{2} = .292 \text{ sl. ft}^2$$

$$I \approx 2 \times Mr^2 = \frac{2 \times 9}{32} \times \frac{(7.5)^2}{144} = .562 \times .391 = \underline{.22 \text{ sl. ft}^2}$$

$$\text{Max } I = 3 \times .2 = .6 + .04 + .133 = .77$$

.6

$$\text{Min } I = .17$$

6,

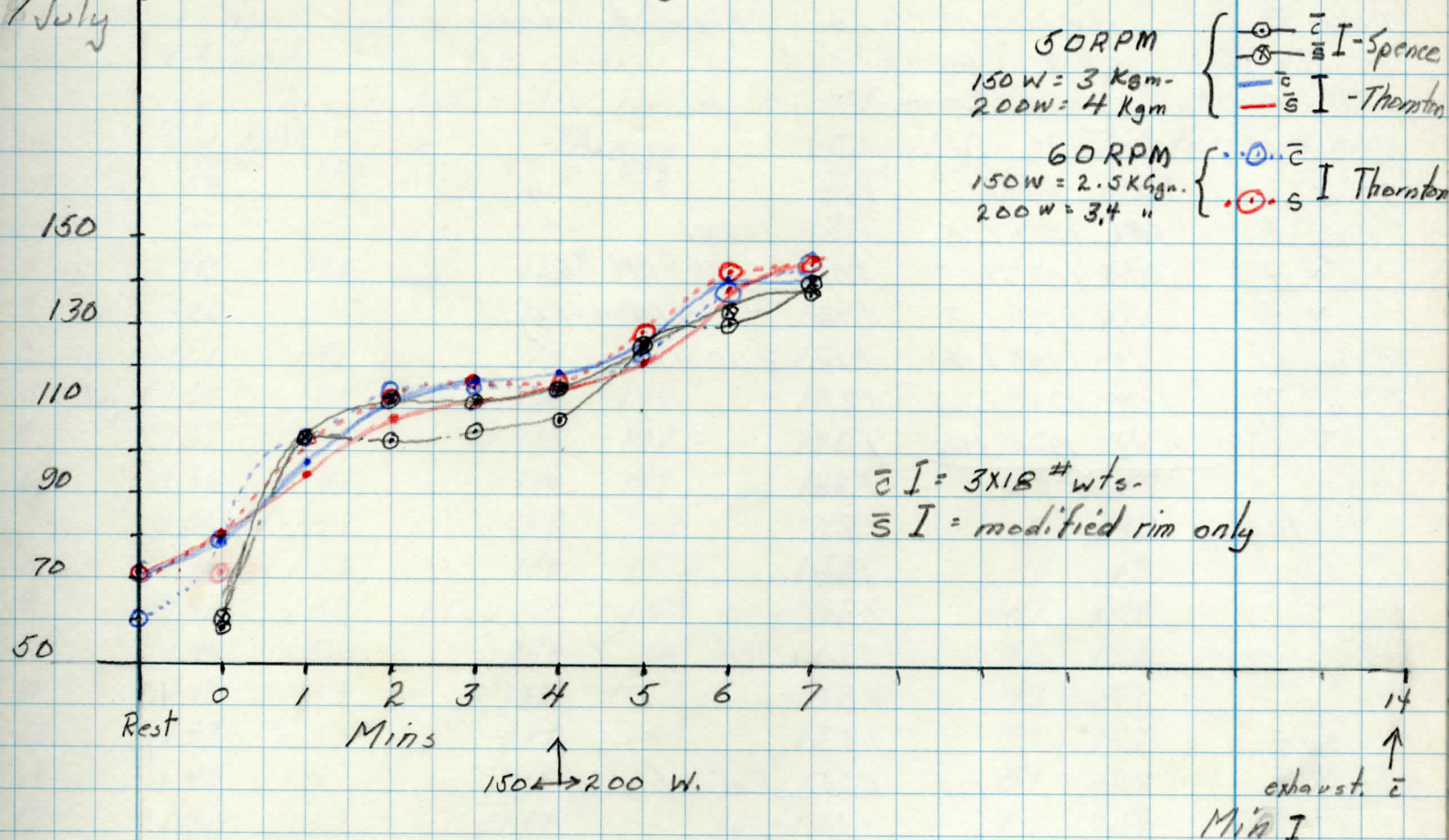
$$\text{Max } I_{\text{equiv.}} = I N^2 = .77 \times 11.6 = 8.94 \text{ sl. ft}^2$$

$$\text{Min } I_{\text{eq.}} = .17 \times 11.6 = 1.97 \text{ sl. ft}^2$$



## Modified Monark Ergometer

27 July



Test. Conds- 82°F room- Spence is experienced ergometer rider. had ridden for ~30 min. prior - Wt. = 161 #

1230 Thornton - Wt. = 210 # Fair cond. had run 1/2 mi prior  
used Monark tach which was later found inaccurate (?)  
Seat extns. was max. for Thornton

| Mins.    | Pulse/m | Spence | Thornton              |
|----------|---------|--------|-----------------------|
| Rest     |         |        |                       |
|          | Max. I  | Min. I |                       |
| 50 RPM 0 | 58      | 60     | 72 72 80 60           |
| 1        | 103     | 103    | 80 79 80 80           |
| 150 W. 2 | 103     | 111    | 95 97 103 103         |
| 3 Kgm 3  | 105     | 111    | 108 112 114 112       |
| 4        | 108     | 115    | 111 116 116 115       |
| 5        | 125     | 125    | 115 119 117 115       |
| 200 W 6  | 130     | 134    | 121 125 128 123       |
| 4 Kgm 7  | 140     | 138    | 129 131 134 129       |
|          |         |        | 135 131 133 134       |
|          |         |        | Min I Max I Min Max I |
|          |         |        | 50 RPM 60 RPM         |

Max I = 3x18 16.1% = 8.9 s.ft.<sup>2</sup> OT min I = .17 s.ft.<sup>2</sup>



28 July

W<sup>m</sup> Thornton on Monark

1230

Subj. ran 1/2 mi prior to these runs

Rest

65 75 60 58

0

65 75 65 70

1

95 96 96 95

150 W. 2

- 102 105 104

2.5 Kg. 3

101 105 105 105 150 W.

4

105 107 105 102 ↑ 60 RPM 3 Kg.

5

114 112 113 110 ↓ 60 RPM 4 Kg.

200 W. 6

120 115 118 118 200 W.

3.2 Kg. 7

120 120 122 120

Min I Max Max 128

60 RPM 126

10

128

129

130

130

132

15

132

135 'Second Wind'

135

135

134

20

135 - Fatigue, quads.

137

136

138

138

25

139

138

139

140

142 - increased fatigue, quads.

30

145

144

143

142

142

35

142

143 225 W. load

150 ↓



## 28 July Additional runs on Monark

Runs were again made in non-airconditioned rooms. ~80°F & fans - Ear lobe cardio tach used - bike tach. checked O.K. this time - Thornton, Spence + Thomas ran. Thomas hadn't ridden for months. Monark max I - 3.4Kgm - 60RPM - 200W

| Time | Pulse BPM | Spence                       | Thomas | Thornton | Thornton (same run) |
|------|-----------|------------------------------|--------|----------|---------------------|
| Rest | C.Tach    | EKG                          | C.Tach | EKG      | Min. C.Tach.        |
| 0    | 58        | 63                           | 65     | 63       | 70 38 146           |
| 1    | 115       | 126                          | 112    | 126      | 105 (39 146         |
| 2    | 120       | 135                          | 123    | 135      | 121 40 146          |
| 3    | 127       | 141                          | 124    | 141      | 124 41 147          |
| 4    | 132       | 144                          | 130    | 144      | 125 42 148          |
| 5    | 135       | 147                          | 135    | 147      | 125 43 147          |
| 6    | 136       | 147                          | 140    | 147      | 130 44 147          |
| 7    | 136       | 147                          | 145    | 147      | 128 45 149          |
| 8    | 144       | 156                          | 150    | 156(?)   | 128 46 149          |
| 9    | 145       | 159                          | 150    | 159      | 132 47 149          |
| 10   | 144       | 156                          | 150    | 156      | 135 48 148          |
| 11   | 143       | 153                          | 153    | 153      | 135 49 147          |
| 12   | 143       | 153                          | 157    | 153      | 132 50 147          |
| 13   | 146       | 159                          | 158    |          | 135 51 147          |
| 14   | 147       | 159                          | 157    |          | 135 52 150          |
| 15   | 146       | 162                          | 159    |          | 135 53 149          |
| 16   | 150       | 162                          | 159    |          | 134 54 150          |
| 17   | 152       | 162                          | 159    |          | 130 55 150          |
| 18   | —         | 159 <sup>ear piece off</sup> | 157    |          | 133 56 151          |
| 19   | 144       | 165                          | 158    |          | 132 57 150          |
| 20   | 151       | 168                          | 159    |          | 135 58 150          |
| 21   | 155       | 162                          |        |          | 139 (59 150         |
| 22   | 154       | 165                          |        |          | 138 60 150          |
| 23   | 153       | 165                          |        |          | 140                 |
| 24   | 154       | 168                          |        |          | 138 61 158          |
| 25   | 154       | 168                          |        |          | 141                 |
| 26   | 155       | 168                          |        |          | 142                 |
| 27   | 153       | 165                          |        |          | 141                 |
| 28   | 153       | 165                          |        |          | 143                 |
| 29   | 155       | 165                          |        |          | 141                 |
| 30   | 153       | 171                          |        |          | 144                 |
| 31   | 155       | 148(?)                       |        |          | 144                 |
| 32   | 156       | 171                          |        |          | 144                 |
| 33   | 155       | 168                          |        |          | 144                 |
| 34   | 156       | 171                          |        |          | 145                 |
| 35   | 156       | 171                          |        |          | 145                 |
| 36   |           |                              |        |          | 145                 |
| 37   |           |                              |        |          | 144                 |



## Monark Calib-

| 50 RPM      | kgm | 60 RPM | 70  | $\frac{8}{8}$ |
|-------------|-----|--------|-----|---------------|
| 200 W - 4   |     | 3.4    | 2.9 |               |
| 225 W - 4.4 |     | 3.8    | 3.2 |               |
| 250 W - 5.0 |     | 4.2    | 3.6 | 2.37          |
| 150 W - 3   |     | 2.5    | 2.2 |               |

Calib scale - C. Tach-

1 min!



Aug. 10 ~ 10:30 cardioasc. test area - ~72°F + fan

Thomas - 175

Thornton - S 214½ F-212 -

Thornton started heart rate controlled test + went to 140 BPM (225 W) + equip failed -

Thomas 'warmed up' at 2 + 3 Kgm 60 R.P.M. 1 min. ea. + then 4 Kgm 60 RPM (237½ Watts) - bags at 2-3 min 5-6 + 8-9(7) min.

Thornton warmed up at 3 + 3.5 Kgm 60 RPM 1 min. ea. + then 4.2 Kgm - 60 RPM (250 W) for 30 min + 45 sec at ~80+ RPM

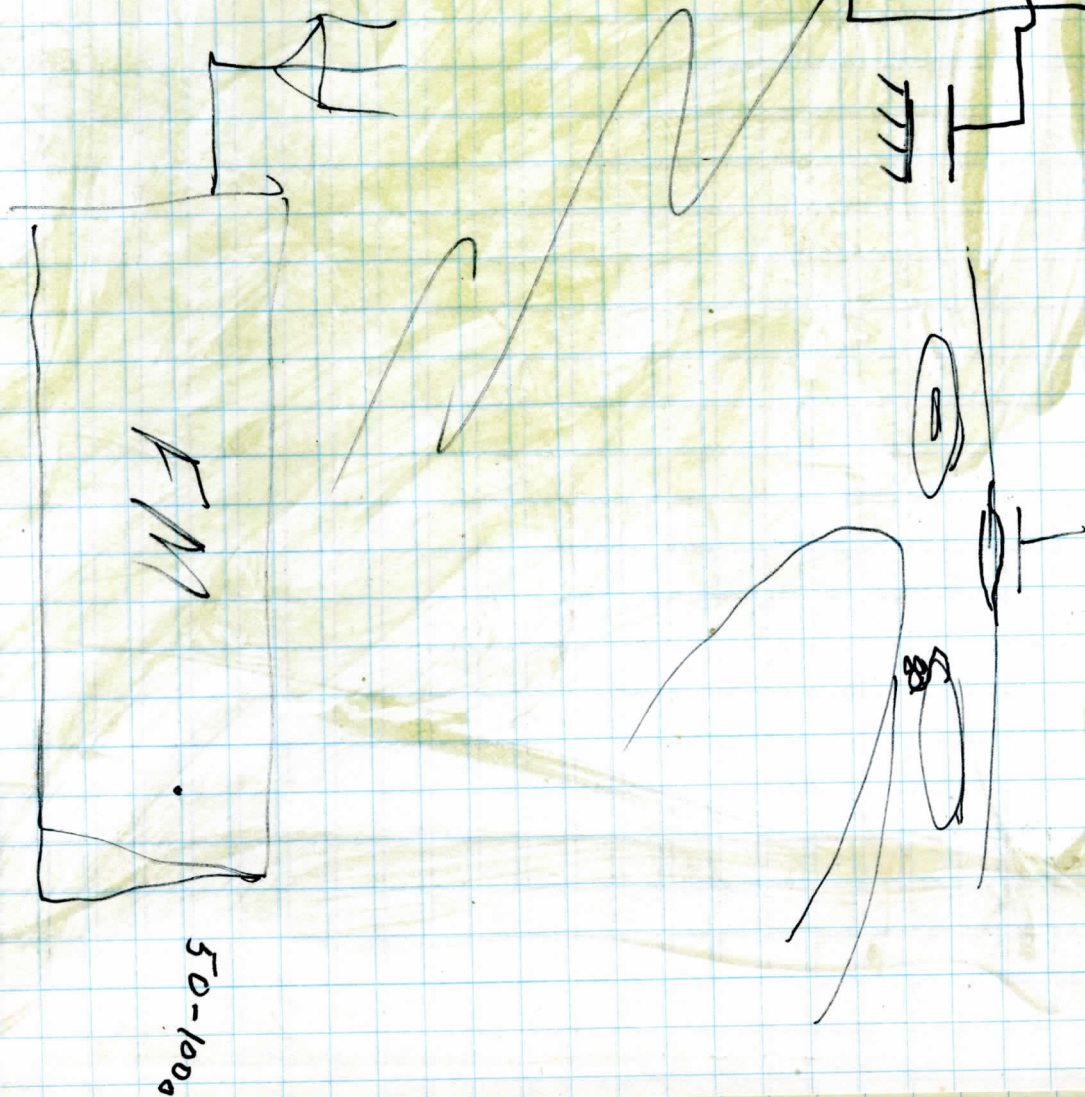
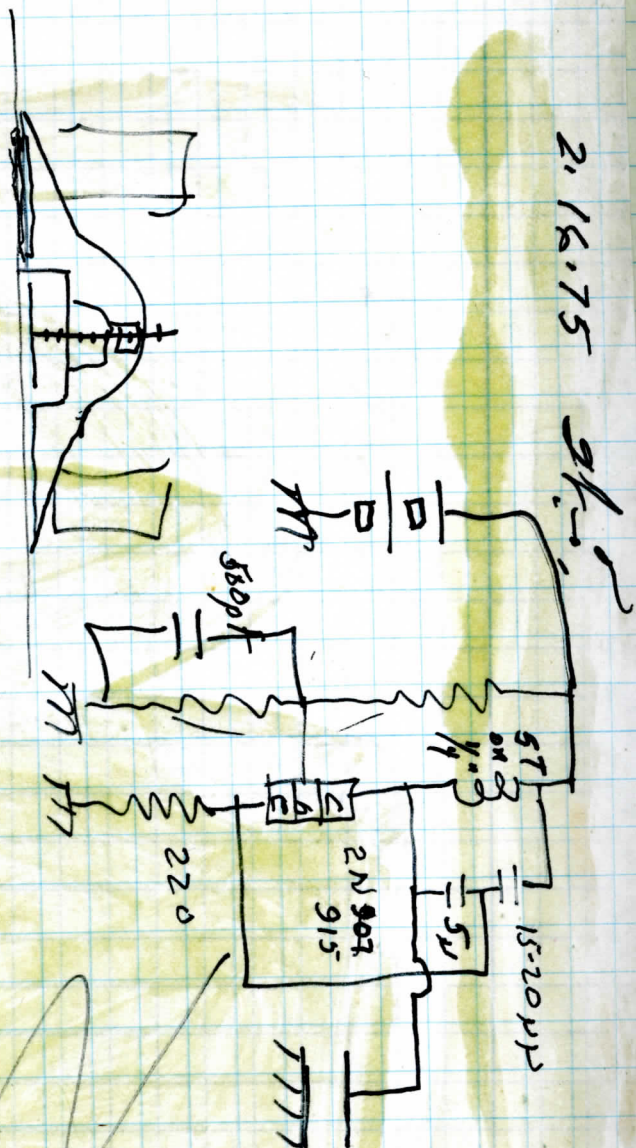
W. Thornton

Time

|          |     |
|----------|-----|
| Rest     | 73  |
| 0        |     |
| 1        |     |
| 2        |     |
| 3        | 134 |
| 4        | 142 |
| 5        | 142 |
| Bag < 6  | 144 |
| 7        | 145 |
| 8        | 145 |
| 9        | 143 |
| 10       | 150 |
| Bag < 11 | 148 |
| 12       | 149 |
| 13       | 150 |
| 14       | 148 |
| 15       | 150 |
| B-3 < 16 | 152 |
| 17       | 150 |
| 18       | 152 |
| 19       | 150 |
| 20       | 152 |
| B-4 < 21 | 152 |
| 22       | 152 |
| 23       | 150 |
| 24       | 153 |
| 25       | 153 |
| 26       | 152 |
| B-5 < 27 | 150 |
| 28       | 152 |
| 29       | 152 |
| 30       | 152 |
| 31       |     |
| 32       |     |



2. 18.75

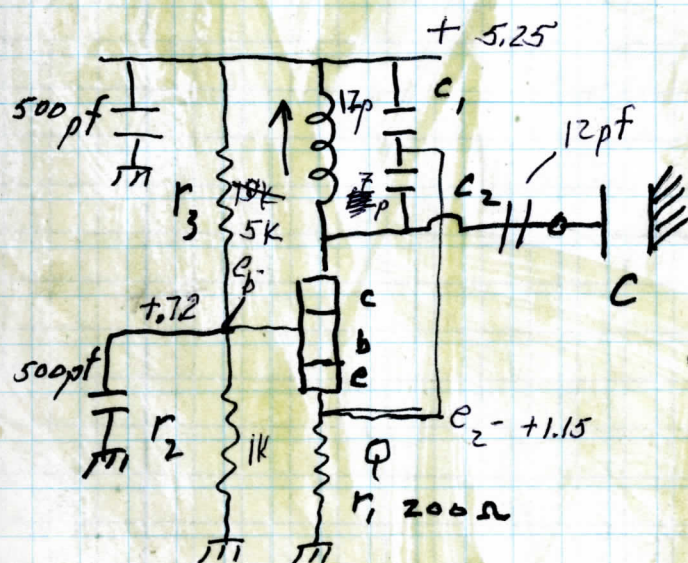
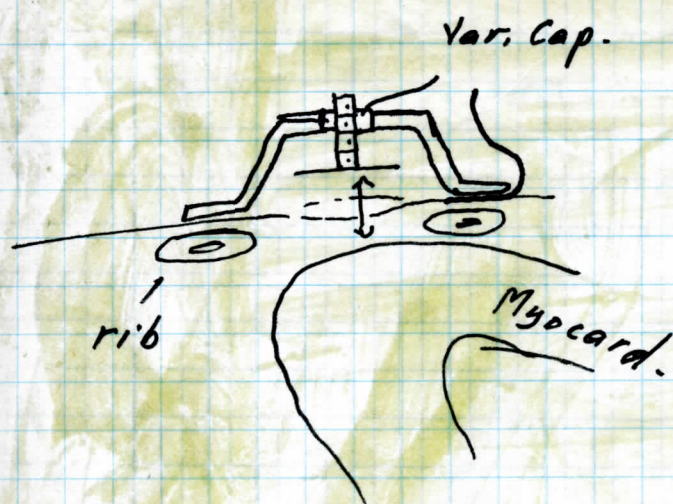




APEX/Phono CG

2.16.76

p-1



Q1 - 2N915

$$C = \frac{8.85 \times 10^{-12} \epsilon_r [(N-1)A]}{t} \text{ pF} \quad \text{or} \quad A = \frac{Ct}{8.85 \times 10^{-12} \epsilon_r} \quad \text{for } N=2$$

t = dielectric thickness - cm

A = area - cm

 $\epsilon_r$  = dielectric  $\kappa$  rel to air.

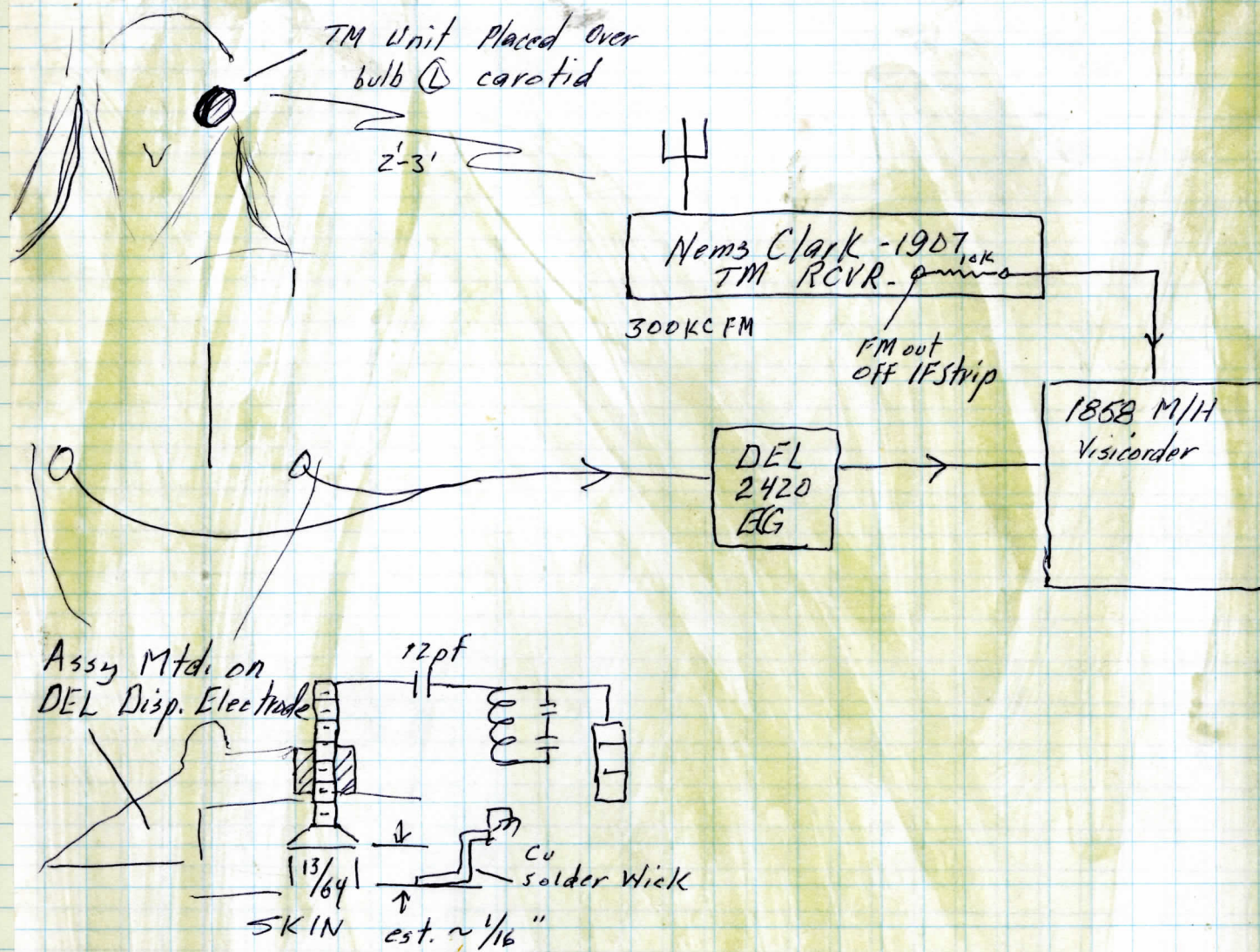
$$= \frac{5 \times 10^{-1}}{8.85 \times 10^{-12}} = \frac{5}{8.85} \times 10^9 \sim 5.6 \times 10^8 \text{ cm}^2$$



A/EGG

12.17

P-2

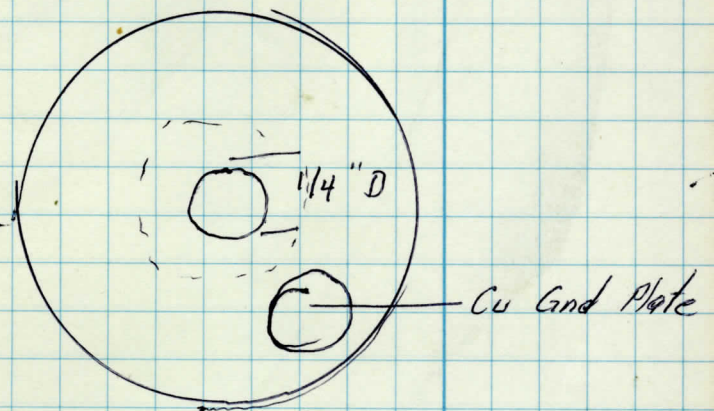
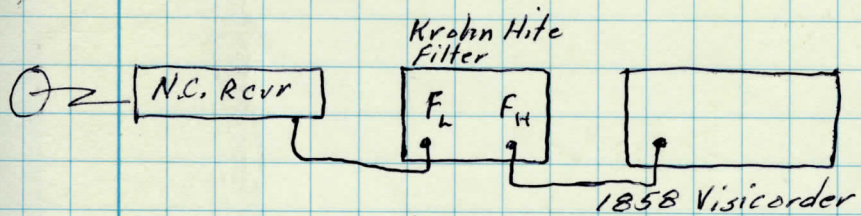
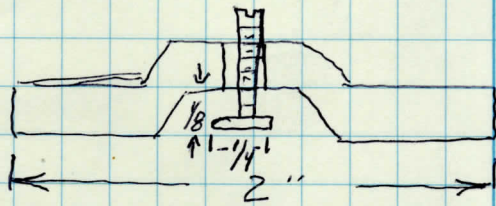
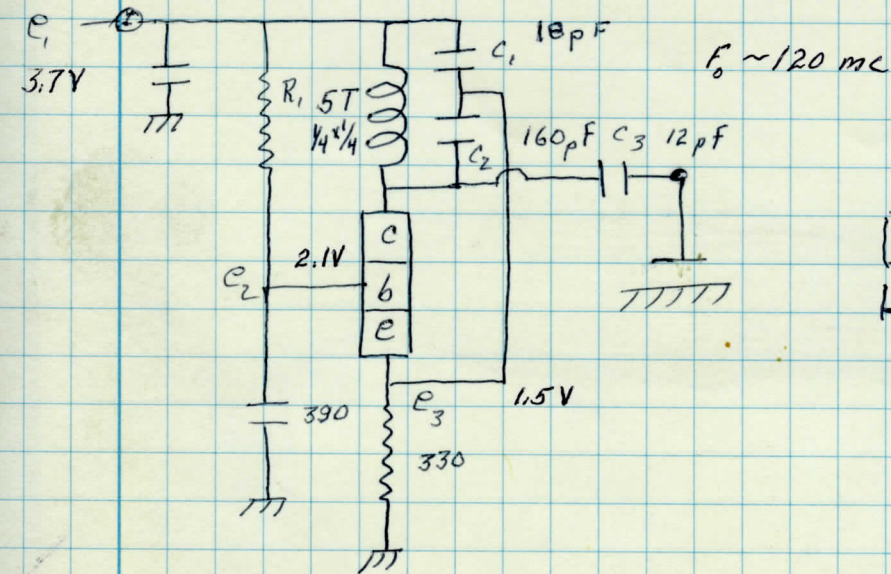


in this arrangement a series of demos of the carotid pulse were made - device worked well - was surprisingly stable for above lash up - Only LF pulses were obtained in absence of good HP Filter - Will make a rigid, shielded unit for phono & apex. demo - (see P-3) - Bridge arr. used was unstable mechanically

see P-126



2-18



See Records on P-127

Xmtr was placed ~ over apex 5L1CS (WT)