25

Ergometry May 1967? 2pp.

NATIONAL
Made in U. S. A.

COMPUTATION NOTE BOOK

43-648

Course [redacted]

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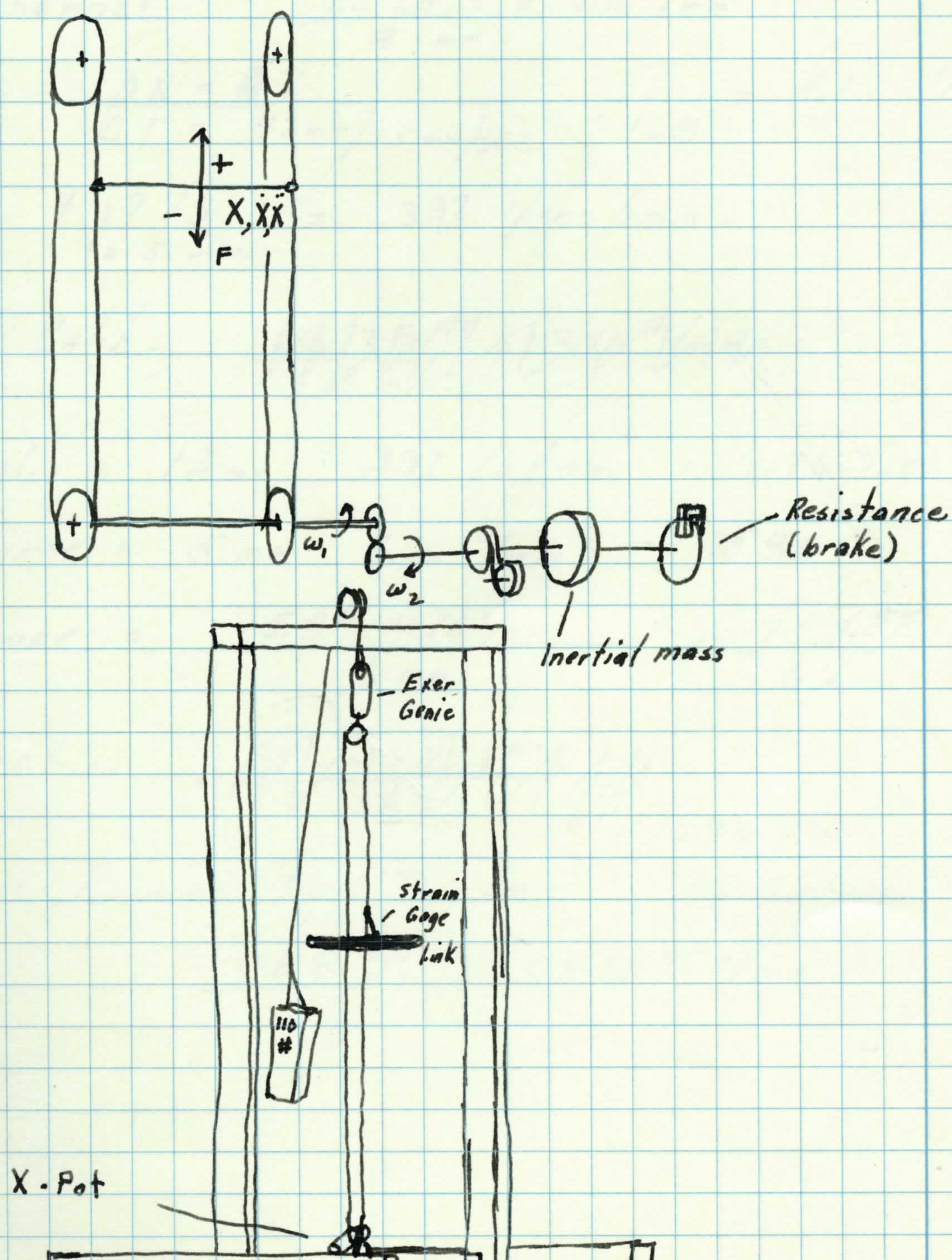
Following lose of previous records the ergometer ~~was~~ and "exergenie" was set up + additional short records made.



Wed. May 3
~~Friday~~

Calibration Wts - A - 5593 gm (12.33 lb.)
B 2565 + 3310 = 5875 (12.95 lb.)
~~5593 +~~
~~8158~~
25.28

$\frac{\Delta X}{\Delta T}$

X - 1 mm = .175 ft.

42 mm / 25 mm

Force Channel - $\frac{25.28\#}{8\ mm} = 3.16\#/mm$

7 / 1.68

Velocity - $\frac{\Delta X = 7}{\Delta T = 42mm/25mm/sec}$ $\frac{7}{1.68} = 4.17\ '/s$

$\frac{4.17\ '/s}{10.5\ mm} = .397\ '/sec/mm$ -

Power Calib - ~~$\frac{25.28\#}{8\ mm} = 3.16\#/mm$~~

Vel. = 12 mm · .397 '/s/mm = 4.76 '/sec

Force = 5 mm · 3.16 #/mm = 15.80 #

Power = $\frac{15.8\# \cdot 4.76\ '/s}{6\ mm} = \frac{75.2\ \#'/s}{6\ mm}$ 12.5 $\frac{\#'/s}{mm}$

379

Work - ~~· 10 mm · 75.2 #'/s~~

98/25 mm/sec = 3.92 sec

Power · 12 mm · 12.5 #'/s/mm - 12.5 #'/s = 150. #'/s

3.92 s
588 '#

265
279 #'/s
221

$\frac{588\ \#'}{10} = 58.8\ \#'/mm$ -

16 July '70

No exercise countermeasures program is being imposed by the medical directorate on Skylabs missions, rather it is being left to the crew office which at present has no definite plans. There are no muscle performance testing procedures planned pre + post flight. At present only the bicycle ergometer and 'Exergenies' are programmed to go. The following data / information is needed:

1) Review of bed rest + flight data to predict events
   A) Look at energy costs
2) Data on use of Exergenie in flight
3) Attempt to document effectiveness of exercise as countermeasure.
4) Data on effectiveness of selected forces
   A) original ergometer
   B) bed rest studies
   C) Wilford hall studies
   * D) Do ergometer c̄ varying I
   * E) Do casting of arm c̄ selected exercises
   * F) Develop evaluation methods
5) Data on Mk. I - drugs. etc -
   A) All SWRI studies

16 July '70

B) Zero G studies

c) Simulated O G studies

20 July Spent day c̄ Ord at S.A.M. Triebwasser reviewed bed rest study using O G simulator (MK-I). The studies were conducted 22 March - 13 July '69 and 30 Nov. '69 - 21 Mar. '70. Each test had 8 subjs. 4 exercised and 4 controls. The first 5 wks. was a control period in which each and every subj. exercised followed by a 6 wk. total bed rest (24 hr./day monitoring - allowed up to defecate - could raise arms to rest to turn pages and feed themselves - otherwise carried - were fed a fixed diet - few subjs. lost wt.) study concluded by a 2° 5 wk. control period. 'Total body exercise' on the MK-I was 3 x 20 min./day at 3×10^5 Ft./lb. day (or 120 L O_2)(or 600 K.Cal.). First study used Tech. Inc. O_2 computer which had errors and 2° used flowmeter/baggery. Avg. work rate was 73% max. O_2 (treadmill). Max. rate on O G Mk I was 90% as compared to Gey's 1G work of 60% max. O_2 (treadmill).

Some results were:

Red cell mass decreased but more pronounced c̄ exerc.

Forearm plethysmography showed periph. vasc. resistance was maintained c̄ + s̄ bedrest.

There was ↑ urine output c̄ ↑ NaCl loss in controls

On Bruce test immed. p̄ bed rest controls had av. decrement of 33% (4-6 mins.) while subjs. was 14% (2 min.)

Subjs. showed no max. O_2 decrement at 9 days while controls

25 Sept. Jerry Craig - Sect Chief 3471
Murray Neil, Morrison, Walter Bobo } GE 3966 } Rm 706 B-2

Fred Dawn B.7A Rm 272 Testing

Art Hinners B.29 Rm 107 Owns Chambers

Slope at 10^{-2} H.P.

$$\frac{\Delta T}{\Delta W} = \frac{250-80\ °F}{5 \times 10^3 \text{ Ft. lbs.}} = \frac{1.70 \times 10^2}{5 \times 10^3} = .34 \times 10^{-1} = 3.4 \times 10^{-2}\ °F/\text{ft.}\#$$

Work in big 4': 100# at 1"/sec - 8' x 12 = 96"

~~96 x 10^2~~ - 800 #/ft

Temp. rise $= 3.4 \times 10^{-2} \times \cancel{96}\,8 \times 10^2 = 27.2\ °F$

Work/cycle $= \frac{8'}{12} \times 10\# \times$ cycles =

6.66 '/#

Avg. Work rate for curves.

① $\frac{2.19 \times 10^3 \times 6.66}{30 \times 60} = \frac{1.39 \times 10^3\ \text{ft/\#}}{1.8 \times 10^3\ \text{sec}} = 7.73\ \frac{\text{ft/\#}}{\text{sec.}}$

$= \frac{7.73}{5.50 \times 10^2} = 1.4 \times 10^{-2}$ H.P. !

CK - $\frac{90\#/m \times 6.60\ '/\#}{60\ "/m}$ or $9 \times 1.1 = 9.9$ ft/#/sec or $\frac{9.9}{5.5} \times 10^{-2} = 1.8 \times 10^{-2}$

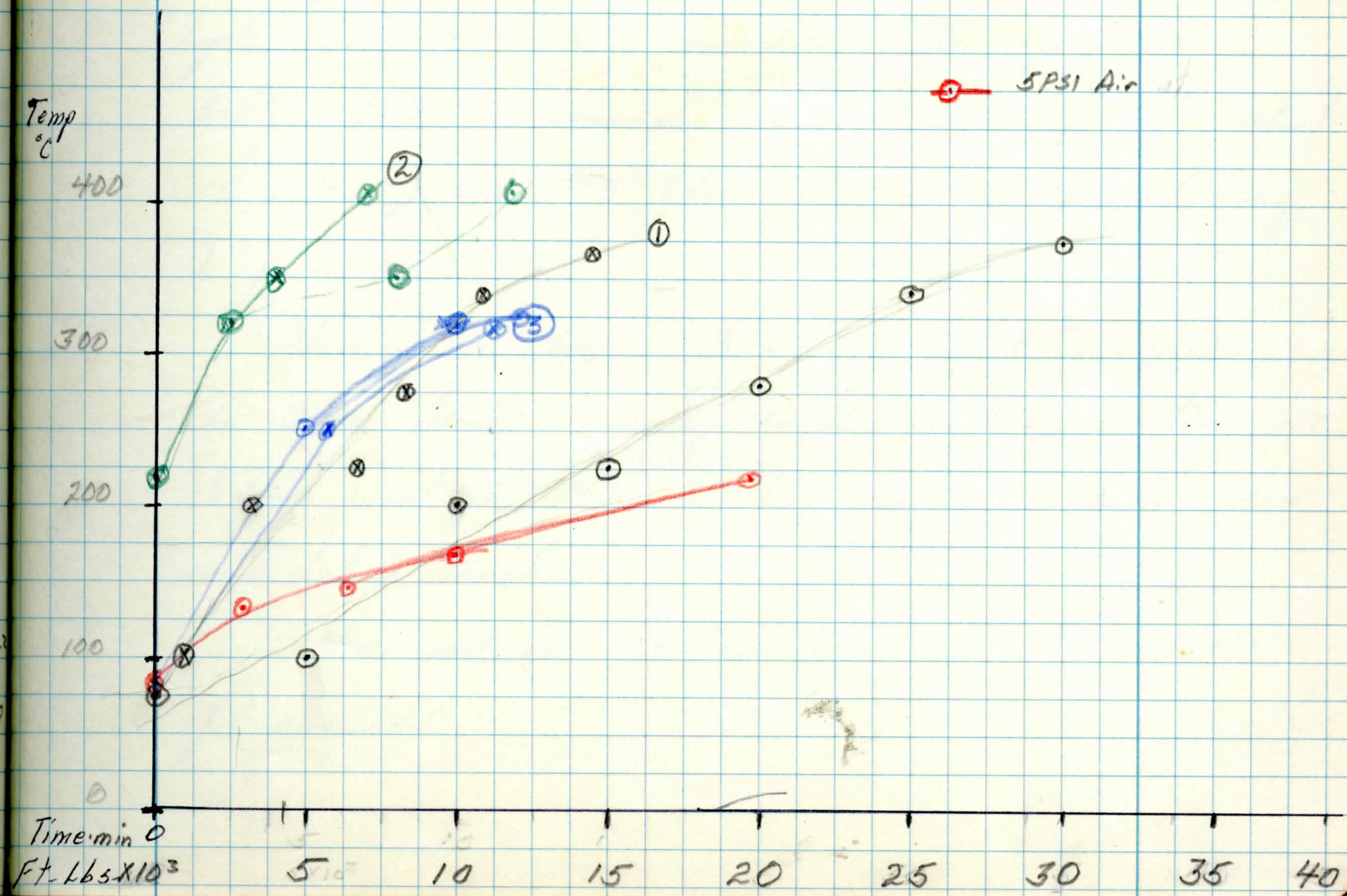
≈ .02 H.P.

③ $\frac{6.66 \times 1.9 \times 10^3}{17 \times 60} = \frac{12.7 \times 10^3}{1.020 \times 10^3} = \frac{12.4\ \text{Ft/\#}}{5.50 \times 10^2} = .0226$

100#/4.5 x 10^3 '/# = x 10^{-3}

25 Sep '70 Once again around the Exergenie (now 'Exergym')

Deke wants to be 'shown' why ergometer is better.
Exergenie was flown on Apollo 7-10 $\bar{c}$ reported heating and other problems. A modified Exergym was developed and 'tested' by Diversified Products Corp. 309 Williamson Ave. Opelika, Ala. This unit has been flown $\bar{c}$ complaints of fraying. P.B.I. cord wears out.
As a start the temp. rise on the Exer-Gym is plotted below. Temp location or ambient conditions are not specified (74°F assumed) $\bar{c}$ a displacement of 8" (sinusoidal) at a force of 10#.



28 Sep. '70

A quick look will be taken at the Exergym in a chamber. N.A.S.A. red tape precludes the use of local chambers so will scrounge use of SAM unit - Drilled 3/8" hole 5/8" deep in capstan of unit and will use Y.S.I. rectal probes and will limit length of pull by knots and measure force by a spring scale.

This was simulated in the GYM: The most obvious point is that the force scale is meaningless. There is also ~~tremendous~~ great variation in force during the cycle, easily + 150% of minimum. The rope frays badly. With ~~an nominal~~ indicated load of 10# (actual 15 to 45#) and 1.5' total pull at a rate of say 1 pull/sec.

Using 20# avg. $35. \times 60 = \frac{2.1 \times 10^2}{33 \times 10^3} = .637 \times 10^{-1} = .06$ H.P. the device heated rapidly to the point of smelling hot. Temp. went to 70°C (158°F) in less than est. 30 pulls. Rope was hot to touch.

Will put in chamber tomorrow at ~.1 H.P. if possible.

28 Sep '70.

Compare work under 1 G to 0 G.

Translation of entire body - say 10' in 5 sec.

$$\text{Work} = \frac{1}{2} m V^2 = \frac{170 \times 2 \times 2}{2 \times 32} = 2 \times 5.03 \text{ ¹/\#} = 10.06 \text{ ft. lb.}$$

also shaking entire body: say 3'/sec

$$\frac{170 \times 9}{2 \times 32} = \frac{1630}{64} = 24 \text{ ft. lb.}$$

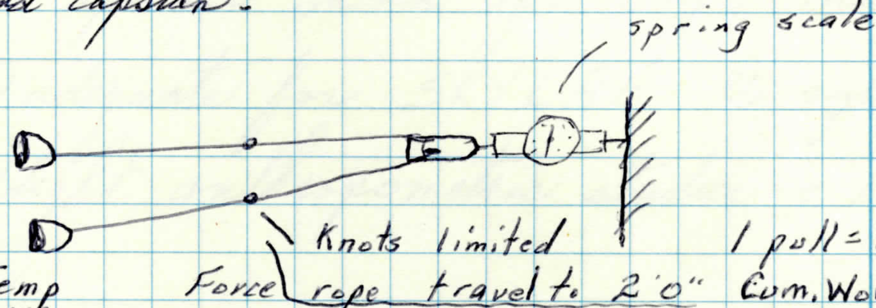
Work in raising arm.
say 1 ft. at 1 ft. sec.
assume

29 Sep. '70

S.A.M. chamber - Salz - Christiansen 23 Y.O. 170#, recorder Moltz.

One hour pre-breathe 100% O_2 - 1330.

The ~~exergenie~~ Exer Gym was instrumented c̄ a surface thermometer Ft. prototype digital 1" from top (swivel) of unit and a second YSI c̄ metal probe inserted in hole in capstans below 'U' of rope + above turn around capstan.



1 pull = 2'0"

Time - secs.	Pulls / Min.	Temp Capst. °C °F	Temp cask °F 1000-n	Force #	Ambient	Cum. Work ft. lb.
60	64	32 = 80	922 =	20.25	72°F	128×25 = 3,200
80		55 = 131				
120	68 132	62 = 143				264×25 = 6,610
150		69 = 156				
180	70 202	75 = 167				404×25 = 10,080
210		79 = 174				
240	74 296					552×25 = 13,800
stop→300	114 390	106. = 223		25.30	humid. 34%	780×25 = 19,500
315		106.5	869 = 131°F			
345		105.				
360		91.	866 = 134°F		73°F	
370		91.				
630		81.	874 = 126°F		73°F 43% H	
mins -						
0		70.	882 = 118°F ~50			
60	57	89.	875 = 125			
120		89.	864 = 136		48% H 74°F	
240		83.5	863 =		74°F	

These results are quite inconsistent c̄ the data from the mfg. Cooling rates were much slower.

2nd Oct. '70 -

Est. temp rise on heat capacity of metal:

$$\Delta T = \frac{BTU}{Sp.H\ Mass} = \frac{5 \times 10^3}{7.78 \times 10^2 \cdot 2 \times 10^{-1}} = \frac{5 \times 10^3}{15{,}56 \times 10^1} \quad 1\ BTU = 778\ ft.\#$$

$$= \frac{5 \times 10^3}{1{,}56 \times 10^2} \approx 3 \times 10 \text{ or } 30\,^\circ F\,!$$

Deke made up his mind yesterday! that Exergenie was adequate for SKYLAB. He agreed to pre & post flight anthropometric studies & ergometric measurements -

20 July 1976 - WEO

List of Data Available for Reviewing Exerciser Studies - Project 16-4630

1. (1) 8-Channel Strip Chart Recording: SYNC, ECG, ———, Qy, Qx, S, Fy, Fx. This strip is marked "TBE-Og Run, March 12 - 14, 1968."

2. (1) Strip Chart Recording O = SYNC, 1 = H.R., 2 = Accel Y, 3 = Accel X, 4 = DISPL, 5 = Force Y, 6 = Force X. This strip is marked "#65".

3. (1) 1200 ft. Reel 16 mm Film, (not full). Sheet inside can is labelled "Zero "G" Protocol AMD CCCU Prototype MKI." Written along edge is "Eddy Current Device." Typed on sheet is protocol for Reels I, II, and III, such as "Constant Force Loading," "Friction Force Loading," "Constant Force Plus Inertia ~~Inserted~~ Force Loading," etc. All runs were made with Major Lawler as test subject.

4. (1) 1200 ft. Reel 16 mm Film (full). Typed label on can says: "Total Body Exerciser (roll 1 of 2), Project 68-002-9, Print #1, Footage - 1200 ft." Taped on can is legend "TBE Simulator BAFB, BR Study?"

5. (1) 800 ft. Reel 16 mm Film (full). Typed label on can says: "Total Body Exerciser (Roll 2 of 2), Project 68-002-9, Print #1, Footage - 800 ft." Taped on can is legend "TBE Simulator BAFB, BR Study?"

6. (1) 1200 ft. Reel 35 mm Film (nearly full). Marks on can are "AMBB Dr. Roberts, April or May - 5 Prints - 2 Positive Reductions - Ellington." On separate tape: "TBE in Weightlessness, Flown at Ellington '68?"

7. (1) 520 ft. Reel 16 mm Film, titled "Man Exercising at Zero "G", WPAFB, Project 67-000-36, Print #1."

8. (1) 520 ft. Reel 16 mm Film, titled "Man Exercising at Zero "G", WPAFB, Project 67-000-36, Print #2."

9. (1) 500 ft. Reel 16 mm Film, labeled "Total Body Exerciser (18 Sept. '67), Project 67-000-45, Print #1, Footage 215 ft."

10. (1) 500 ft. Reel 16 mm Film, labeled "Total Body Exerciser (18 Sept. '67), Project 67-000-45, Orig. Neg., Footage 215 ft."

11. (1) 500 ft. Reel 16 mm Film (partly full). Note on inside says, "Exerciser, Project 16- "

12. (1) 400 ft. Reel, titled "TBE - Og. Study, Dup. Print #2."

13. (1) 16 mm film in small can labeled, "Sandvik Spirator Spring with Integral Band."

14. (1) 16 mm film in smaller can with no label. Very little film in this can.

15. (1) Document entitled, "Calibration and Operation of the Strain Gauge Amplifier and Work Computer." - BK #47225, 30 March '69, signature illegible.

16. (1) Document entitled, "Total Body Ergometer Amplifier and Work Computer Calibration." - BK #47225, 31 March '69, signature illegible.

17. SwRI Final Report, Project No. 16-2145, entitled "Ground Laboratory Total Body Exerciser - Zero-Gravity Simulator," Fogwell and Cox, January 1969.

18. Document - "Instructions for Total Work Computer and Strain Gauge Amplifiers" - Marked S (Total Body Exerciser) 3-15, Wendell R. Peters (SMSB) USAF-SAM, Brooks Air Force Base.

The time one can pedal a bicycle ergometer undue fatigue is a function of not only the amount of work done but also the inertia of the load. Although the ratio of other forces to that of inertia has not been defined for optimum efficiency, there appears to be some minimum amount of inertia required. On a bicycle this amount of inertia is large; consisting of the mass of rider and bicycle. In terms of moment of inertia a bicycle could typically have 14 slug. ft.^{2} (this fortuitously increases c̄ the riders cut.) The MSFC ergometer has only while the Collins has at least . I don't know how difficult it would be to modify the ergometer but it would be definitely be improved by an increase.

In an effort to obtain some quantitative data on the effects of inertia a quick test is being seen locally and these results should be available in a couple of weeks. Another large gain in the bicycle ergometer could have been (could be?) gained by designing for the environment of its intended use.

A simple vector diagram shows the difference--

diagram

Wt the largest vector is now missing and c̄ it any requirement for a seat. The two components of the thrust vectors could be much more economically handled by shoulder-trunk restraints than by a seat and artificial restraints-in the proper direction. Such an arrangement is shown in 2. In addition the arms can supply an effective vector in the same plane and this would provide additional exercise since the forces are cyclic.

diagram

Another consideration is accuracy of work loads based on 1G studies. With a restrain arrangement such as shown in F-2 much more confidence could be placed in the ground based data by tilting the device backward.

If the body's evt. is supported by a free bearing arrangement the differences in energy costs between 1 & 0 G may be estimated.

P-1 rough

The time one can pedal a bicycle ergometer ~~effectively~~ ~~i.e.~~ $\bar{c}$ undue fatigue is ~~related~~ a function of not only the amount of work done but also the inertia of the load. ~~It~~ Although the ratio of other forces to that of inertia ~~to~~ has not been defined for optimum efficiency ~~it~~ appears that in other types of work the ratio may be on the order of

$$\frac{F = MA}{F = MG} \qquad M = \frac{F}{A}$$

$$\frac{M}{MG} \qquad M$$

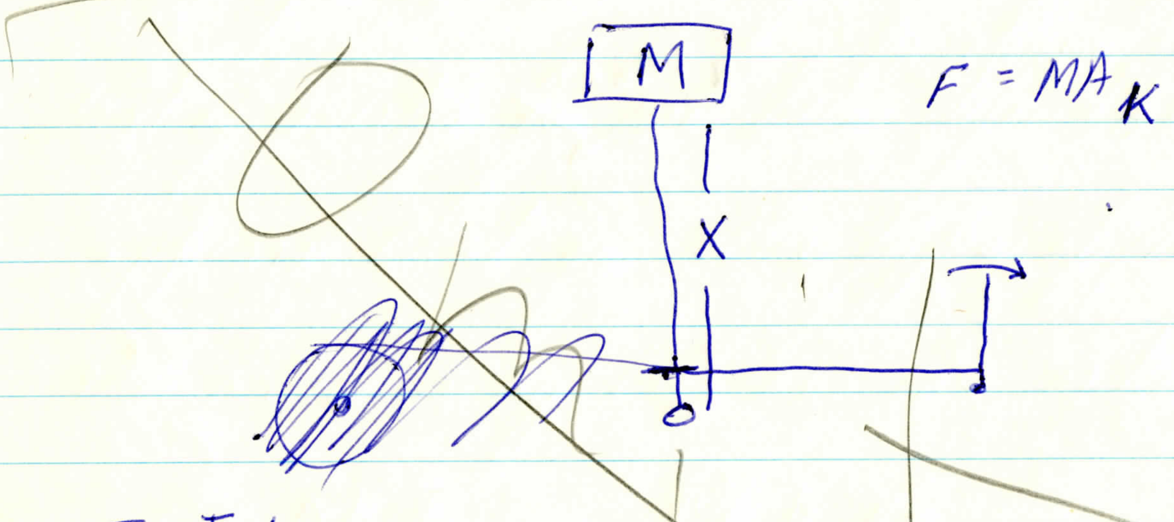
12/.50

there appears to be some ~~minimum~~ minimum amount of ~~int~~ inertia required.

P-2

On a a bicycle this amount of inertia is large; ~~representing~~ consisting of the mass of rider + bicycle.

In terms of moment of inertia



$F = MA \quad K$

$M = \frac{F}{A}$

$I = \underline{T}$

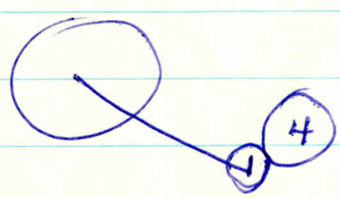
$\times \frac{150/32}{1}$

$T = I\alpha$

$I = \frac{T}{\alpha}$

$T \propto N$

$\alpha \propto \frac{1}{N}$



$\alpha' = \alpha/4$

$T' = 4$

$$\underline{I_{eq}} = \frac{TN}{\frac{\alpha}{N}}$$

$$= \frac{T}{\alpha}N^2 = \underline{IN^2}$$

P - 3

a bicycle ~~has~~ could typically have 14 slug. ft.^{2} (this fortuitously ~~was~~ increases c̄ the riders wt.). The MSFC ergometer has only while the Collins has at least. I don't know ~~what would be~~ how difficult it would be to ~~increase~~ modify the ergometer but it would definitely be improved by an increase.

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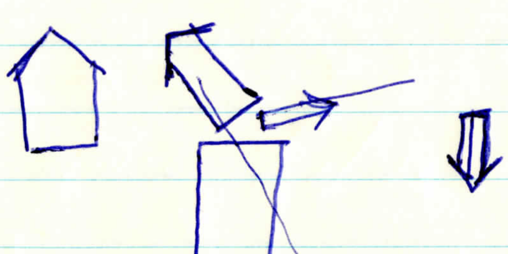
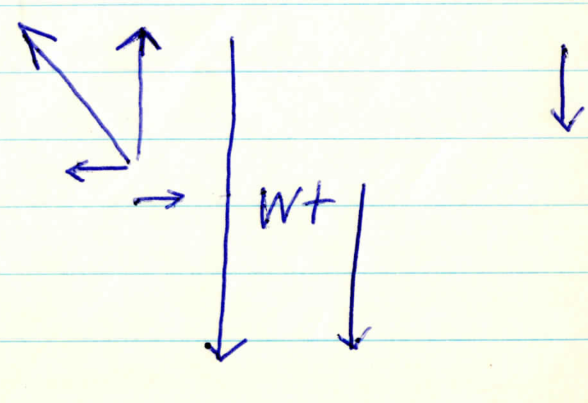
P-4

Another large gain in the bicycle ergometer could have been (could be?) gained by ~~consideration of~~ designing for the environment of its intended use.

Bicycles and ergometers on earth obviously take advantage of the ~~+ G~~ gravitational field by provision of a seat to absorb

A simple vector diagram shows the difference -





As the largest vector is now missing and ē it any requirement for a seat. The two components of the thrust vectors could be much more economically handled by shoulder-trunk restraints than by a seat + artificial restraints. in the proper direction. Such an arrangement is shown in 2.

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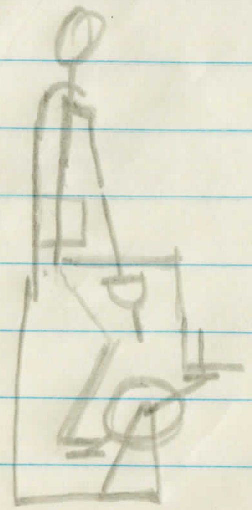
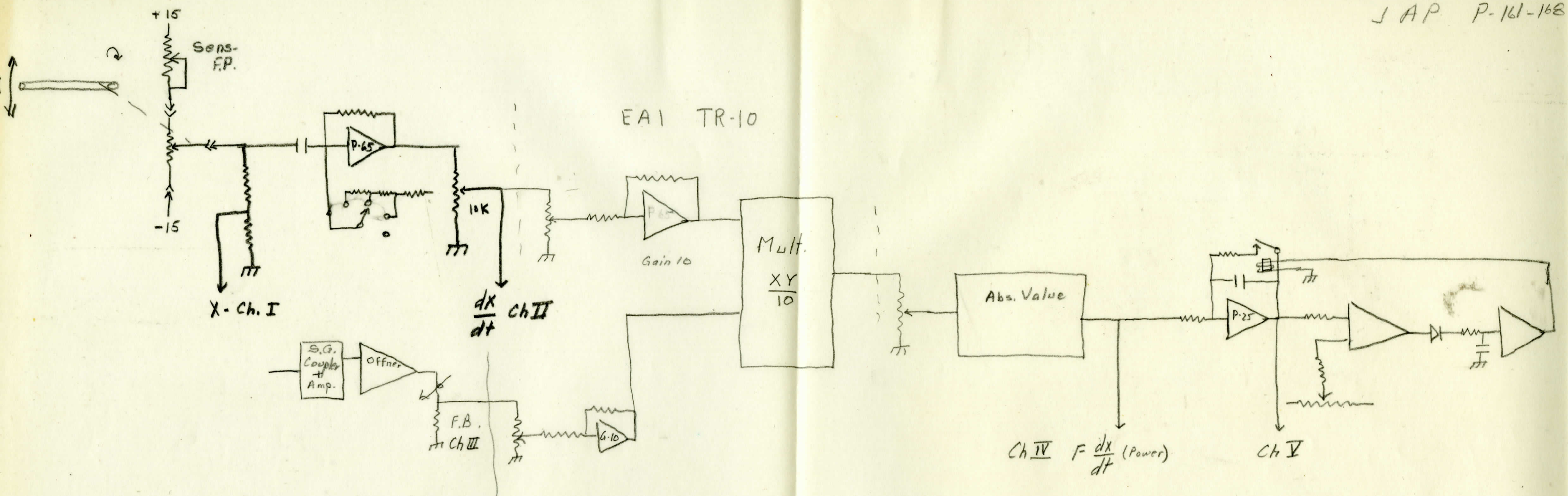


Another consideration is accuracy of ~~ground based~~ work loads based on a 1G studies. ~~It is a~~ With a restraint arrangement such as shown in F-2 much more confidence could be placed in the ground based data by tilting the device backward.

If the body's wt. is

supported by a free bearing arrangement the differences in energy costs between 1 & 0 G may be estimated.

Imp-Plot
Jan 67
JAP P-161-168



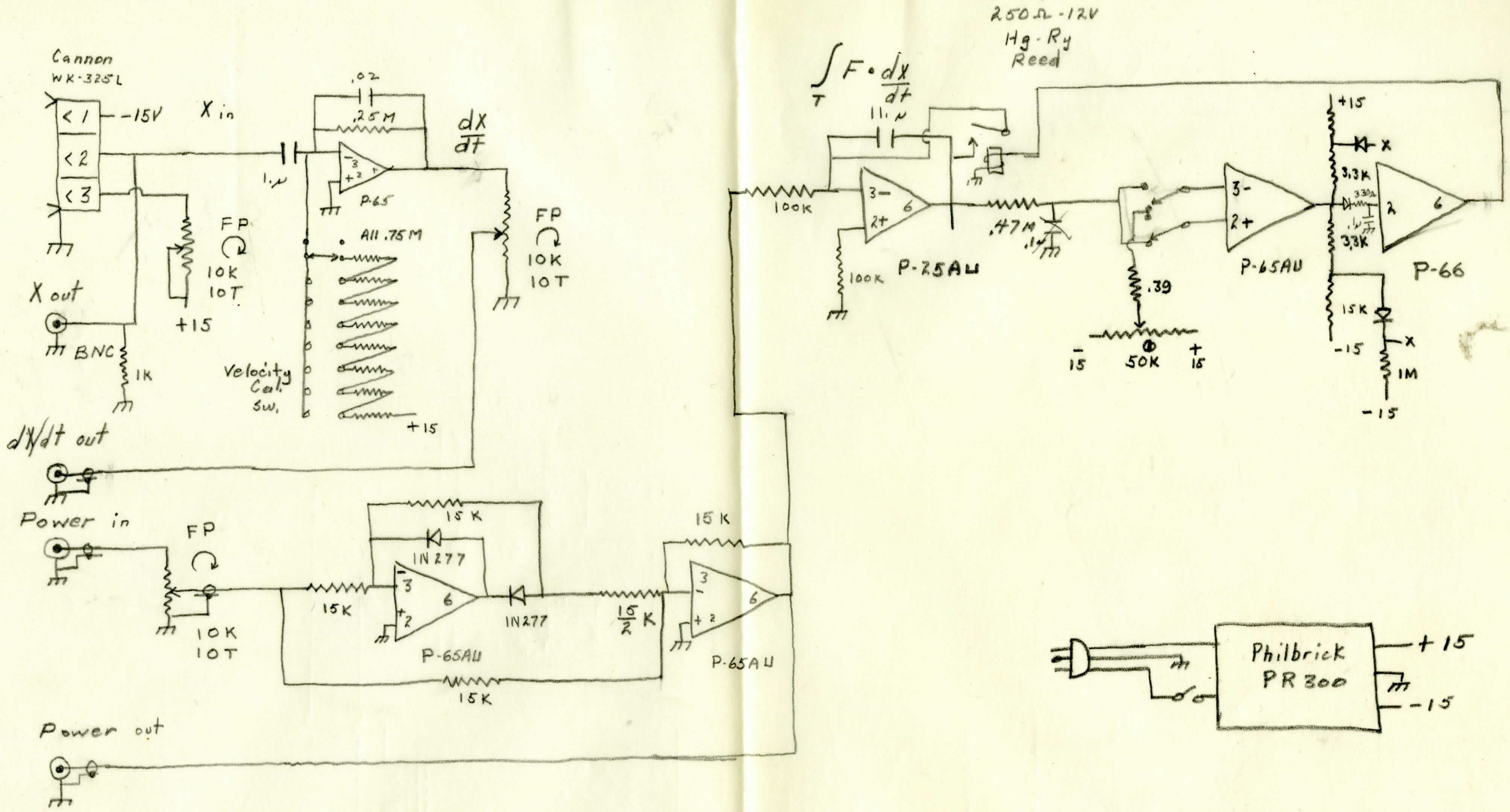
$$\underline{X} \longrightarrow K_1\frac{dx}{dt}$$

$$K_1\frac{dx}{dt},\ K_2\underline{F}orce \longrightarrow \boxed{\times} \; K_3\left(K_2F \cdot K_1\frac{dx}{dt}\right) \longrightarrow \left| K_3\left(K_2F \cdot K_1\frac{dx}{dt}\right)\right| \longrightarrow \int_T \text{Power}$$

Force x Vel
Power

abs val

work



CKt. of Signal Conditioner Chassis

Time	Cal	
1333	Cal – Force	- large pb
		2 small "
		all 3 "
1610	"	Force + X – large
		+ 2 sm
		all 3

start
1325 29 Sep. 70 – BAFB SAM Chamber

1330 Press – Temp Subj: ~~Ericson~~ Christianson

170# – Moltz

Time	T_{core} ° °C	T_{shell} 1000° – F°	Force #	Pulls	Length	Amb °F
0	32	–922.	20-25			72°F
60				64		
1+20 ~~120~~	55			~~68~~		
120	62			68		
150	69			~~70~~		
180	75 →			70		
210	79					
240	90			74		
300	106			114		Humd – 34%
315	106.5	869	25-30			
45	105.					
360	91	866				73°F
370	91					
630	81	874				43% Humid 73°F
0	70	882				48% 73°F
60	89	875	4550-55	57		48% ~~74°F~~
120	89	864				
240	83.5	863				74°F