f. 1

Altazimuth
1864
made for me by Casella

f. 2r

TABLES

FOR THE

DETERMINATION OF HEIGHTS BY THE OBSERVED TEMPERATURES OF BOILING WATER AND OF THE AIR.

ARRANGED FOR USE WITH

CASELLA'S INSTRUMENTS.

23, HATTON GARDEN, LONDON, E.C.

HYPSOMETRICAL TABLES,

Arranged for Casella's Apparatus for measuring mountain heights by the vapour of boiling water, and adapted also for the Zeometer, a small pocket instrument, designed by F. Galton, Esq., F.R.S., and made by Casella, by means of which, with an ounce of water and a drachm of spirit the height of any mountain may be ascertained, and the index corrections of Aneroids and Sympiesometers readily verified.

f. 3r

TABLES

FOR CALCULATING ALTITUDES FROM THE OBSERVED TEMPERATURE OF BOILING WATER AND OF THE AIR.

Tables I and II are adapted from those of Col. Sykes, F.R.S., and of Col. Shortrede, U.S. Table C is by F. Galton, Esq., F.R.S.

To use the Tables I and II:—

1st.— From Table I take the approximate heights due to the boiling point at the upper and also at the lower station.

2nd.—Multiply the difference between them by the multiplier found in Table II. corresponding to the mean of the temperature of the air at the two stations.

f. 3v

EXAMPLE.

Boiling point at Top,

188°3	188° =	12843	
	.3 =	168	
		12675	12675

Do. at Bottom,

206°5	206° =	3085	
	.5 =	260	
8/ 8/		2725	2725

Temperature at Top,

8/ 43	Difference	9950
Bottom, 65		
2)108		
Mean, 54	Multr.	1.049

8/ 1·049 × 9950 = 10437 feet. 3/ 3/

To use TABLE C *with the Zeometer :*

In the event of a considerable portion of the mercury in the stem being outside of the vessel containing the boiling water, a correction must be *added* to the reading to increase it to the degree it would have attained if the entire instrument had been submitted to boiling heat. To find this correction, multiply the number of degrees along which the exposed column of mercury extends, by the multiplier in Table C corresponding to the approximate difference between the average temperature of the tube and that of its bulb.

It will be sufficiently near to the truth, if we estimate the temperature of the tube to be a few degrees higher than that of the air, for an error of ten degrees cannot make a difference of more than twenty feet in the calculated altitude when the zeometer is employed.

EXAMPLE.

Reading of the Thermometer,		209°
First graduation on the exposed part of the stem . . .		180°
Length of exposed column .		29°
Temperature of air,	75°	
Reading of Thermometer,	209°	
Multiplier, ·011 Difference,	134°	

29 × .011 = 0°31.

Corrected read. 209° + 0°31 = 209°31.

2/ 2/ 2/ 2/

Table I.—Showing the elevation and Barometric Pressure corresponding to any observed Temperature of Boiling Water between 214° and180° Fahr.

Boiling point of pure Water.	Approximate height above the level of the sea (or 30·00 inch).	Value of each tenth of a degree in feet of altitude.	Corresponding height of Barometer.
	FEET.	FEET.	INCH
214°	—1013	50	31·20
213	507	51	30·60
212	0	51	30·00
211	+ 509	51	29·41
210	1021	51	28·84
209	1534	51	28·27
208	2049	52	27·71
207	2566	52	27·17
206	3085	52	26·63
205	3607	52	26·10
204	4131	53	25·57
203	4657	53	25·06
202	5185	53	24·56
201	5716	53	24·06
200	6250	54	23·57
199	6786	54	23·09
198	7324	54	22·62
197	7864	54	22·16

f. 5r

Table I—*Continued.*

Boiling point of pure Water.	Approximate height above the level of the sea (or 30·00 inch).	Value of each tenth of a degree in feet of altitude.	Corresponding heights of Barometer.
	FEET	FEET.	INCH
196	8407	55	21·70
195	8953	55	21·26
194	9502	55	20·82
193	10053	55	20·38
192	10606	56	19·96
191	10661	56	19·54
190	11719	56	19·13
189	12280	56	18·73
188	12843	56	18·33
187	13408	57	17·94
186	13977	57	17·56
185	14548	57	17·19
184	15124	57	16·82
183	15702	58	16·46
182	16284	58	16·10
181	16868	58	15·75
180	17455	58	15·41
179	18044	59	15·07
178	18633	59	14·74
177	19224	59	14·42
176	19817	59	14·11
175	20412	60	13·81

f. 5v

Table II.—Table of Multipliers to correct the approximate Height for the Temperature of the Air.

Mean of the Temperatures of the Air, above and below.	Multiplier.	Mean of the Temperatures of the Air above and below.	Multipler.
32°	1·001	50°	1·040
33	1·003	51	1·042
34	1·005	52	1·044
35	1·007	53	1·046
36	1·010	54	1·049
37	1·012	55	1·051
38	1·014	56	1·053
39	1·016	57	1·055
40	1·018	58	1·057
41	1·020	59	1·060
42	1·023	60	1·062
43	1·025	61	1·064
44	1·027	62	1·066
45	1·029	63	1·068
46	1·031	64	1·071
47	1·033	65	1·073
48	1.036	66	1·075
49	1·038	67	1·077

Table II.—*Continued.*

Mean of the Temperatures of the Air above and below.	Multiplier.	Mean of the Temperatures of the Air above and below.	Multiplier.
68°	1·080	80°	1·107
69	1·082	81	1·109
70	1·084	82	1·112
71	1·086	83	1·114
72	1·089	84	1·116
73	1·091	85	1·119
74	1·093	86	1·121
75	1·096	87	1·123
76	1 098	88	1·126
77	1·100	89	1·128
78	1·102	90	1·131
79	1·105	91	1·133

f. 6v

Table C.—For correction of account of exposure of stem.

Difference between temperature of column of Mercury and of the bulb.	Corresponding multiplier.
70	·006
80	·007
90	·008
100	·009
110	·009
120	·010
130	·011
140	·012
150	·013
160	·014
170	·015
180	·015
190	·016

LIST OF PORTABLE INSTRUMENTS FOR TRAVELLERS

Especially arranged by L. CASELLA, for the Members of the Alpine Club.

	£	s.	d.
Alpine Sympiesometer, perfectly compensated for Temperature, in in a Sling Case - - - - -	4	14	6
Mountain Barometer, with Guage Point, in Cistern, reading to 1000th of an inch, with English and Centisimal graduation - - -	8	10	0
Hypsomitrical Apparatus, for Measuring Heights by the vapour of boiling water - £5 0 0 to	6	10	0
Zeometer for do. by ~~the~~ boiling ~~point~~ water	2	10	0
Alpine Minimum Thermometer -	0	7	6
" Maximum Do. - -	0	10	6
" Solar Radiation Do. - -	0	7	6
" Plain Do. - -	0	6	6
Case for the Pocket, in which the last named Thermometers are mostly placed - - - - -	0	6	0

f.71

Do. for Insulated Solar Maximum	£ s. d.
Thermometer - - - - -	0 5 0

The Graduations of the above Thermometers are etched on the stem, and can be verified at Kew, at a small extra cost, if required.

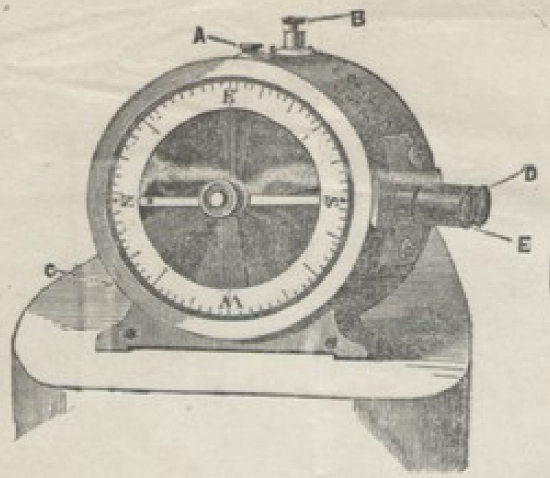
Hygrometer in Pocket Case - -	1 10 0
Clinometer, with level, sights, scale of instruction, rack work, &c., arranged to fix on the Alpine St~~ic~~k	2 ~~5~~ 10 0

i/c Stick

Prismatic Compass, Box Sextant, Artificial Horizon, &c. &c. The Alpine Note Book, with Papers and Instructions for Observations on Mountain Districts.

N.B.—It has been recommended by the Alpine Club that where Casella's numbered Instruments are used their numbers should be entered in the note book.

F. 8



CASELLA'S POCKET ALTAZIMUTH,

IMPROVED AND MODIFIED BY THE KIND ASSISTANCE OF

FRANCIS GALTON, Esq., F.R.S.,

ALTITUDES, AZIMUTHS, COMPASS-BEARINGS, CLINOMETRIC DEGREES, LEVELS,

All obtainable by a strong and handy, but accurate little Instrument, whose diameter is 2¼ inches, thickness 1¼th inch, and weight 5½ oz.

Description.—The Altazimuth contains: 1. An unusually good Azimuth Compass, with Aluminium Disc; 2. A Weighted Disc for altitudes. Both these are graduated on their edges, and are read off through lenses, in a far more simple manner than the ordinary prismatic compass. The Instrument is ready for use immediately the catches, that hold the discs, are released. 3. One face of the Aluminium Disc is plainly engraved, to serve as a good ordinary compass. 4. One face of the Weighted Disc is divided, to serve as an ordinary Clinometer, the box of the Instrument being furnished with a fiducial edge.

A. Stops or liberates the compass, on being made to slide backwards or forwards.

B. Acts similarly on the Clinometer, on being pushed in or drawn out.

C. Is to be pressed in as a steady pin, before reading the compass.

D. Is the lens of the compass; and E. is that of the Clinometer. To adjust these lenses, screw them a little, in or out, as required.

To Use the Instrument.—Hold it vertically for altitudes, horizontally for azimuths, and so direct it that on carrying the eye from the hair line to the object about to be observed, they may be exactly in line. Then read off the division covered by the hair line.

Accuracy of Performance.—The performance of an Azimuth Compass is well known and appreciated. That of the Weighted Disc must clearly be far more delicate, inasmuch as the directive force of gravity is enormously greater than that of terrestrial magnetism. Both discs are graduated to degrees. A careful observer will read off to tenths.

Index and other Errors.—The principle of the weighted Disc admits of these being discovered, checked, and eliminated. Two different readings may be obtained from the vertical circle, by observing with the Clinometer's face first to the left and then to the right—the mean of these is clearly independent of index error. Again, by taking similar observations of the image of the object, as reflected in water, &c., two additional readings may be obtained; making four readings in all, or one on each quadrant of the disc. The mean of these four must be almost wholly independent of instrumental error. A skilful observer, anxious to make the most of this little Altazimuth will therefore find it superior in reliable value to Instruments of far greater bulk, weight, inconvenience, and pretensions. An intelligent traveller furnished with the Altazimuth may, by its use alone, map his country, take the height of mountains, and the dip of strata, and correct his position by very respectable astronomical observations. For, reckoning his accuracy of observation as being correct to one-tenth of a degree, his latitudes will be right to six miles, and his longitudes, by occultations, or (if he has a telescope) by Jupiter's satellites, to within thirty miles.

L. CASELLA,

SCIENTIFIC INSTRUMENT MAKER TO THE ADMIRALTY,

THE VARIOUS GOVERNMENT DEPARTMENTS, AND THE LEADING FOREIGN GOVERNMENTS,

23, HATTON GARDEN, LONDON, E.C.

f.9

Observe with alt az smaller
⊙ (Clock across reading ounce) ⊙

with face right		with face left	
Alt.	time by watch	Alt.	time by watch
34°.50'	X h. 16 m	31° 30'	X h. 15 m.
34 55'	X 21	31 30	X 19
34 55	X 22	31 45	X 26
35 5	X 23½	31 50	X 25
35 55	X 31	32 10	X 29
36 0	X 32	32 10	X 30
36 0	X 35	32 40	X 32½
36 10	X 37½	32 45	X 33½

By Map. Long. N. Lat. 7' west of Green
Lat. 51° 30'. N.

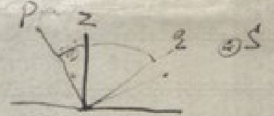
34.50 | 31.30
| 31.30
34.55 | 31 45
| 32.10
35.55 | 32.10
36. – | 32.40
4/21.40 | 6)11 45
mean 35°.25' | 31.57
31. 57
2/3. 28
1. 44 error index

345

Observ.d Time at X. 19m by watch ⊙ 33° 15' March 20th 1865
(corrected by protractor – for errors of centre)

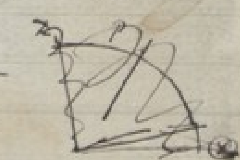
⊙ decl. 0. S. about 0°. 2'
refr

For Latitude with face left			Inst. face Right	
Alt.		time by watch	Alt	time by watch
43 30	37.30	XI 27	40°. –	XI 23
	37	XI	40°	XI. 45
43 45	37 15	XI 46½	40. 10	XI. 45
43 45	37 15	XI 47	39. 50	XI 50 (good?)
43. 30	37 30	XI 52	40. 5	XI. 51
43. 25	37 35	XI 53	40. 10	XI 51
43 30	37 30	XI 54	40 15	XI 55
43 30	37 30	XI 57	40. 10	XI 56
43 35	37 25	XI 58	40. 5	XI 57
43 30	37.30	XI. 58	40° –	XI 59
43 25	37.35	XII.	39. 50	XI 59½
43 30	37.30	XII. 1	40 –	XII 2½
~~40 –~~		~~XII. 8~~	39. 50	XII 4
37	37.	XII. 9	39 55	XII. 4
36 35	36 35	XII 12½	36 45	XII. 6
36 40	35 40	XII 14	36. 30	XII 7
			40.	XII 12



37. 35
40. 10
2/77 45
38°.52 app alt ⊙
~~1.4~~
~~38 50~~ true ⊙
38°.51

ZE PZ = ZS – ES



add zenith
ZS = ~~90 – 37° ...~~
ZS = 90 – 38°. 51' = 51. 9
ES = – – – . 2
51. 7
Error – 23
51. 30.

f. 10r

Geological Survey of Ireland,

Office, 51, Stephen's Green, Dublin,

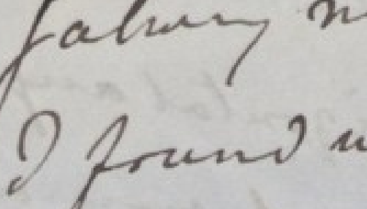
Oughterard April 25 1865

Dear Sir

You asked me to give you my experience of Casella's Altazimuth I have it now about five month & find a great fault with it - that is - when taking horizontal angles you cannot see the object you are looking at & read the angle at the same time - I have always to put something (generally a pin) in the line of vision which pin & the reading of the angle I can see at the same time through the glass but otherwise

f. 10v

I find that I have to take my eye
from the glass to see the object
I was afraid that I did not see
it right so I lent it to Proff
Townsend of the Queen College
Galway not telling the fault
I found with it & he returned
it to me with the same objection
He suggested that there should be
a little pin fixed in rings right
opposite the object glasses that



could be left down
when the instrument
was in its case but

f. 11r

could be pushed up when it was
being used - I was thinking that
if there was an oblong slit cut in
the band right opposite to the lens
that the object & reading might
be seen at the same time One of my
Colleague J. J. Foot also tried
it & could not see the object
& reading at the same time
& had to use a pin or the edge
of his knife to effect it
If I have used the instrument
wrong I shall be much obliged
if you put me up to the proper
way of using it - I also

f. 11v

object to the price I think £4-4
too much for it & so does every
one that has seen it - In other
respects it is a beautiful little
instrument & does its work admirably

Truly Yours

C Henry Kinahan

To Francis Galton Esqr F.R.S.

July 20/64

My Dear Mr Galton.

At length I have the pleasure of sending you one of the little instruments not yet named nor described. If you can aid me in any way by a giving me a name for it I shall be still farther in your debt. On receipt of your favour the other day I was on the point of completing six of them — and have been

f. 12v

to our friend & find
there are some leading
was thus at a loss how to
reply with further grace
As I am about to protect the
arrangement perhaps you
will kindly withhold it for
a few days - and if there
be any way in which you
think it may be still more
improved I shall feel happy
& obliged by your kind suggestions
The steps are 1 one to steady
the compass when in use

f. 131

2 the shortest of two together to liberate the compass ~~and~~ ~~3 the longest~~ and is moved by a spring – and 3 the longest the tube of which is drawn out to liberate the Thermometer – with sincere thanks for all your kindness & forbearing indulgence in this matter

Your Yours truly

J. Mosella

P.S. My Man was told that you had left & would be away for some time & therefore brought the instrument back – but I will send it to you again on your kindly letting me know of your return –

f. 13v

The Altazimuth

Carellas

July 5. Septr. 1864

F Galton Esq F.R.S. &c &c

Rutton Gate

Septr 7/64

Dear Mr Galton,

I am most glad to find you have returned, and I now have the pleasure of handing you one of the — — as yet unnamed — the one sent is in the state of 6 which I finished but finding I could still improve the light by making 3 good 5/8 holes in the Clinometer plate. 2, improve the power of the Compass and 3 the Clinometer I at once did these two as above, and have now sent them to Kew for examination — with the

request that they may be
sent to me by Saturday morning
and when they reach me
I will send you one - or
both if you prefer it -
the Clinometer Stop is drawn
out by the top to set it at liberty.
the Compass is pushed horizontally.
and the steady pin acts in
the usual way - but for
the name - that seems difficult
Geometer was excellent for the
instrument that served one purpose,
but this serves for four perhaps

f. 15

you can scarcely be aware
here. I believe you were
also so good as to propose
shewing it at the Association if
you can I shall feel farther
indebted, I have got a neat
wood Cut which I propose
altering to correspond with a
description yet to be printed and
in this. I would with your
permission insert your
Name as the lenses are
undoubted yours.

I am faithfully yours

J. J. Masella

Fr...
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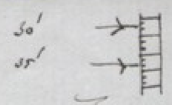
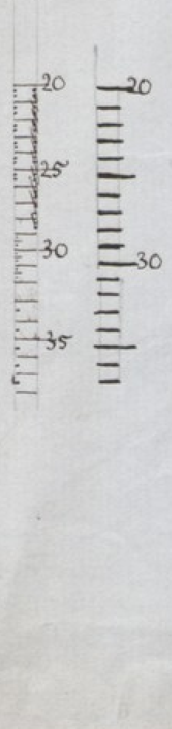


dividing into 20' the eye subdivides into half less than half or more than half or into 10' 5' or 15'

or else divide into 30' or have 10' graduation on index

or divide to 30 or vernier to 3' 5 or 6



Numbers to the 5' as well as to the 10's

Finer graduations

Dot the half degrees.

Vernier, or index, adjustable read to 5' (? 2' 3' or 6')

Lens of double power

? compound microscope

Level across

Stand

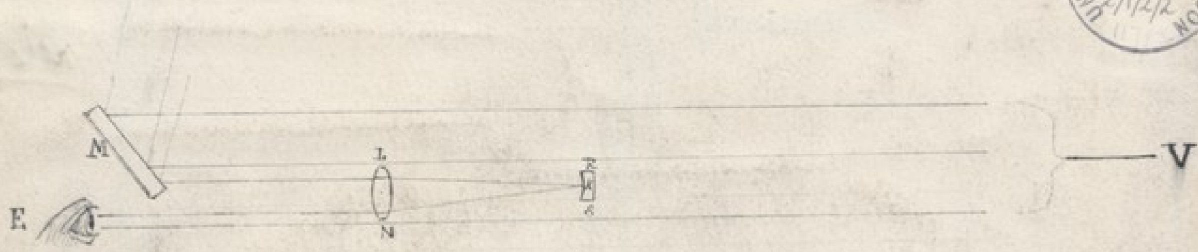
Stop must be altered.

The thread only for compass.

Turn Over

Principle of the Hand Heliostat

Heliostat



LN is a convex lens having a screen, RS, attached to it, whose surface is at the exact focal distance of LN

M is a mirror flashing rays partly on LN & partly free of it.

E is the eye of the signaller looking partly through LN and partly to the side of it

The rays represented in the figure are those from some one single point on the Sun's surface. the rays that are flashed clear of the lens go towards some "Vanishing Point" V. those that strike the lens are converged upon the screen to a point K. But, the rays that proceed from K & impinge on the lens are reduced back to parallelism with those that left the mirror, and an eye at E, looking through the lens, sees K in the exact direction of V

What is true for the rays from any one point of the Sun's disc is true for every point, therefore the rays from the entire disc form a circle at K, which appears to the eye at E as exactly the same shape and size, and in the same direction, as the area covered by the entire flash. ———

Turn Over.

F 1r (1)

A Hand Heliostat

for flashing the direct rays of the sun upon a distant station.

It is proposed as a subsidiary instrument for making very distant signals, on board ship or elsewhere, in sunny climates.

Francis Galton

The accompanying instruments give the appearance of a brilliant and glistering star of light at 10 miles distance, and are distinctly visible to the naked eye for 20 or 30 miles. An aperture of only 1/10th of an inch square in the screen before the mirror gives a speck of light clearly discernable to the naked eye at a miles distance under favorable circumstances.

Action of the Instrument.

The flash from any plane mirror upon distant objects covers an area which (if it were defined) would invariably appear, to the person who holds the mirror as of exactly the same shape and size as the sun itself. Now this instrument supplies the appearance of a mock sun which, exactly overlays that area. — Consequently, by bringing any part of that mock sun, — something after the fashion of a sextant observation, — over the distant station, the signaller may be sure that his flash is directed upon it.

By simple combinations of flashes, and groups of flashes, letters and numerals can be made.

This shews the appearance of the field of view of the instrument. The spot in the mock sun brought down upon a distant promontory. —

Turn over

Wave Engine
1871 – 2

Energy contained in Waves

The Energy in a unit of surface water agitated by waves consists of two elements, which can be shewn to be equal to one another viz:

1. ~~The~~ orbital movement ~~of~~ in a vertical plane, the diameter of the orbit being the height from trough to crest of the wave
2. The elevation of the centre of the orbit above the plane in which the unit of water would lie, supposing the water to be still

Hence as Energy $= W \cdot \frac{v^2}{2g}$ & $v = \frac{\pi \cdot \text{diam: of orbit}}{\text{periodic time}}$

& $2g = 64.4$

Energy of unit of wave water

$$= \underline{\text{twice}} \left\{ \frac{\pi \cdot \text{diameter of orbit}}{\text{periodic time}} \right\}^2 \times \frac{1}{64.4}$$

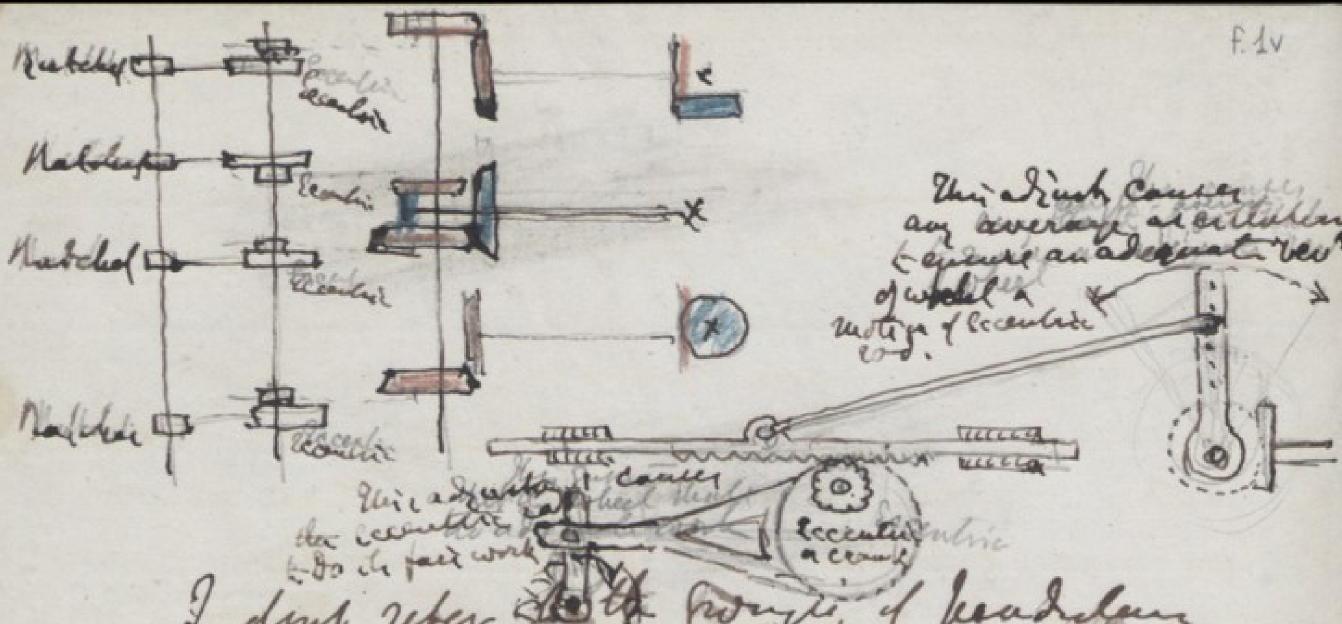
$$= \frac{\pi^2}{32.2} \left\{ \frac{\text{diameter of orbit}}{\text{periodic time}} \right\}^2$$ of which half is due to motion & half to elevation

$\log \pi = 0.497$

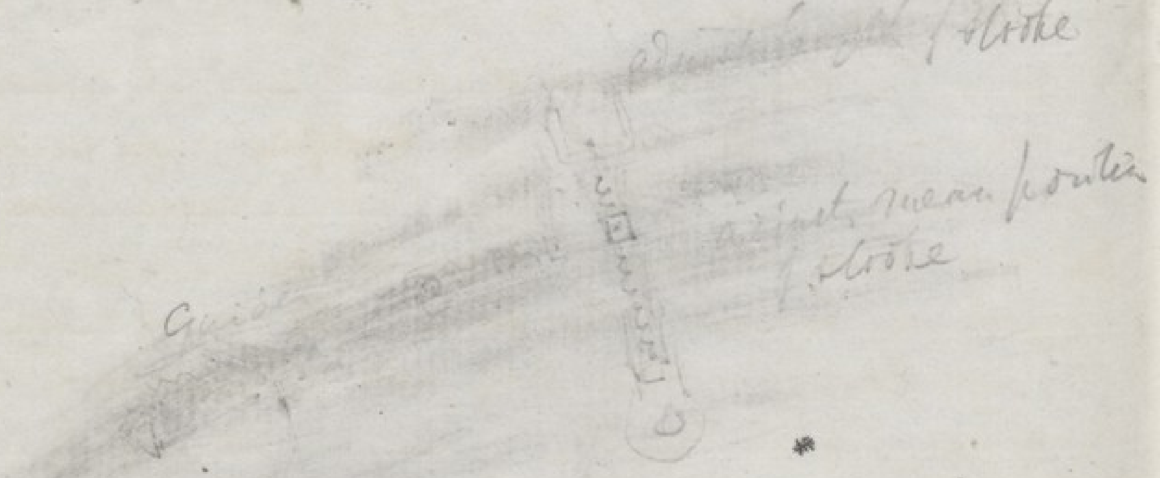
$\log \pi^2 = 0.994$

$\log 32.2 = 1.508$

$\log \frac{\pi^2}{32.2} = \bar{9}.486 = \log 0.306$



I dont refer to the weight of pendulums or to the working & action of water on board ship because they are not controlling
It may however be used to work detents



Goodeve p. 68

Consists of (4) parts (1) vessel or ~~fixed~~ object part attached to — (2) floating or suspended object part attached to
(3) connecting link work (4) gear moved by ~~that~~ ~~alternate~~ or link work

A wave Engine: that is, a machine by which waves may be made to perform useful work. on board vessels or on shore

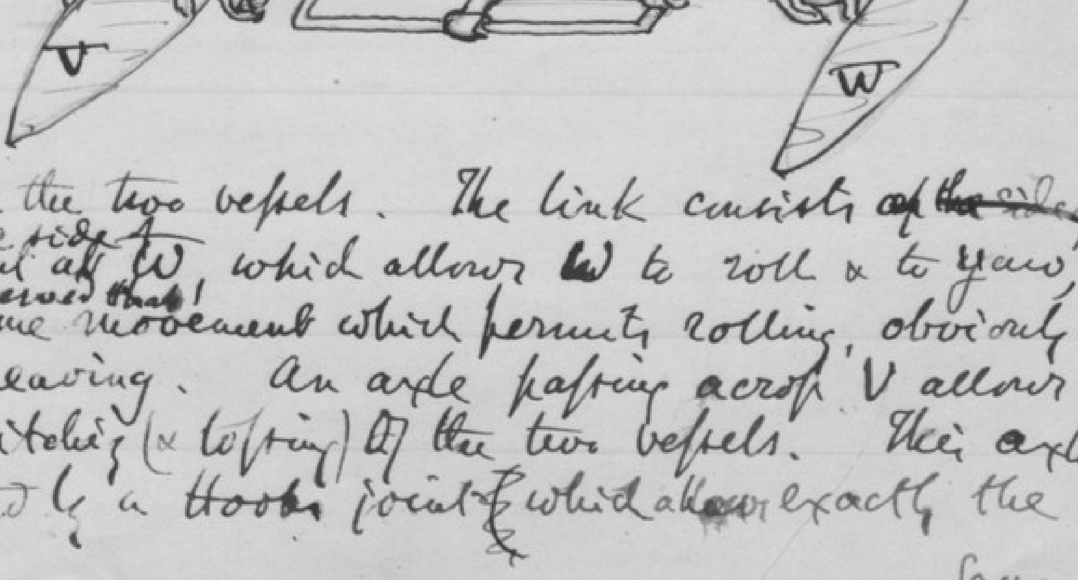
It is well known, that waves give motion in various directions to bodies floating or suspended in water. Also it is well known, that two such bodies have considerable relative motion even though they be near together. The object of my wave engine is to make a part of the force ordinarily wasted in making these motions to perform useful work. I link one body which either floats or is suspended in water, to another such body, or else to one that is stable, and I cause the movements of the link to ~~[illegible]~~ give motion to my machine. The fund of power available to work ~~for~~ my wave engine may be estimated by the difference between the sum of the movements of the two bodies when they are unattached and when they are linked together by my machine.

To ~~explain~~ illustrate the principle on which the wave Engine is worked I will suppose a buoy to be attached to the end of a long pump handle which projects from the side of a ship. ~~Then~~ It is clear, that as the buoy rises and falls, relatively to the side of of the ship, it will move the pump handle up and down and will perform useful work. The ~~buoy will be restrained by the force it has to overcome in working the pump in the freedom of its movement up & down but by so far as it has been so restrained will~~

buoy will be restrained in the freedom of its up-and-down movement by the constraint of working the pump, which constraint is the ~~[illegible]~~ measure of the force by which the pump will be worked. The same may be said of a hinged keel or other board swinging to & fro up & down or backwards & forwards in the wash of the waves.

But in these simple cases, where movement is restricted to mere swinging, only a small part of the energy contained in the various movements of the waves can be turned to account, the remainder being wasted in straining the hinges. In my wave engine all the varied movements of a floating body may be made to contribute simultaneously to its working power, and I gain this result in the way which I now proceed ~~propose~~ to describe, in general terms. The case, I will consider, is that of two vessels linked together, part of the motions derived from the waves being transferred to one vessel & part to the other. This will ~~include all~~ obviate the necessity of describing simpler cases and as regards a more complicated one in which the larger part of the movements are transferred to one of the vessels I will for convenience sake, allude to it afterwards.

It will be found, that all possible movements of two vessels relatively to one another may be treated as combinations of six ~~and only six~~ primary movements and that a "link" on the principle shewn in the diagram will afford complete liberty, within the range of its joints & slides, to the vessels connected by it.



V, W, are the two vessels. The link consists ~~of the slide of~~ two Hooks joint at the side of W, which allows W to roll & to yaw, ~~and~~ & it will be observed that the same movement which permits rolling, obviously including heaving. An axle passing across V allows the relative pitching (& tossing) of the two vessels. This axle is connected by a Hooks joint & which allows exactly the

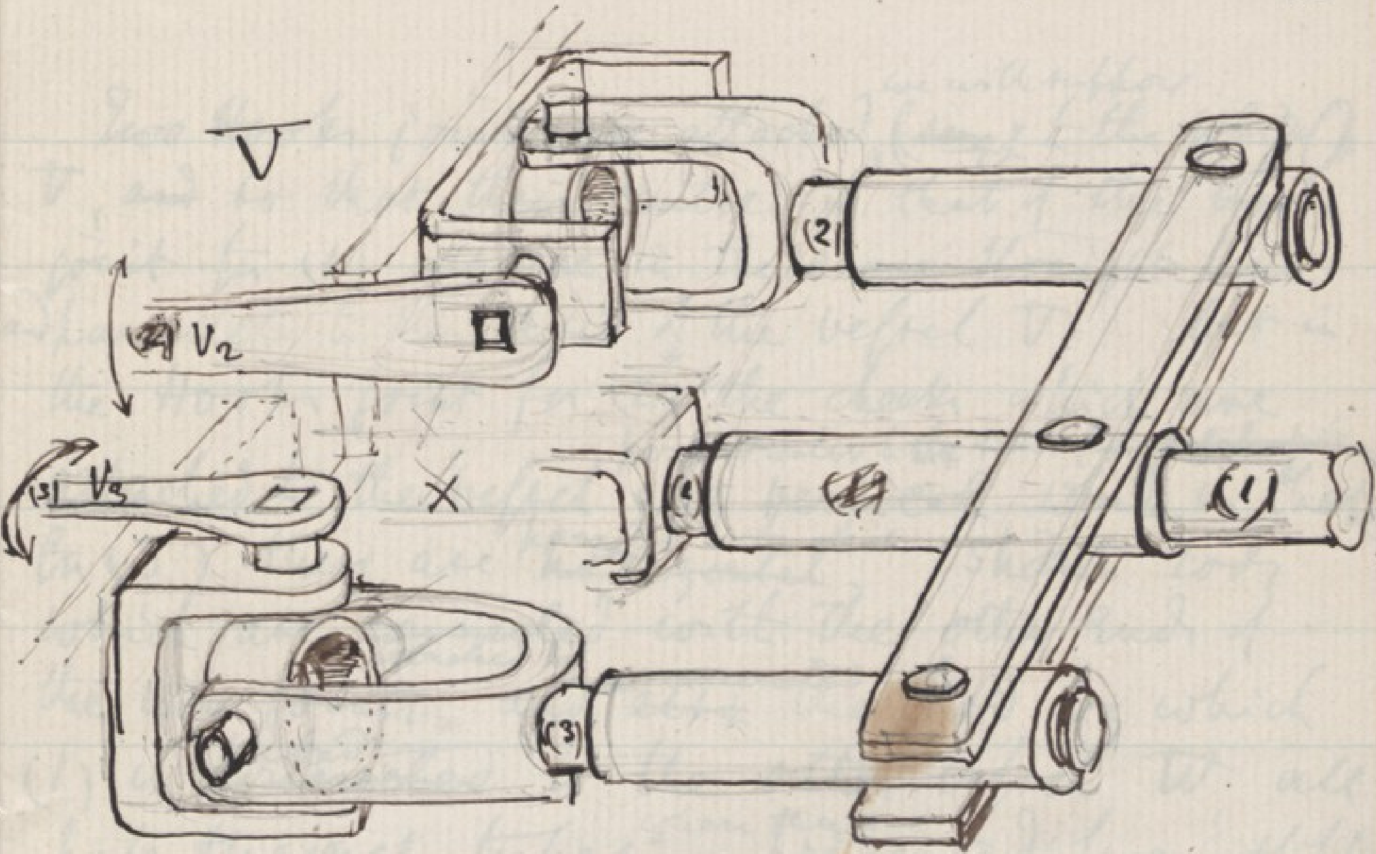
same

same movements of rolling (inclusive of heaving) & yawing to V that the first mentioned joint did to W. & And lastly, the two Hook's joints are connected by a sliding ~~link~~ arrangement, which permits the vessels to approach or separate from one another, within the range of the slide.

In the case I am about to consider, I will suppose the three motions consisting of (1) the relative pitching of the two vessels, (2) the rolling of V and (3) the yawing of V to be transferred to a wave engine on V and the other three motions consisting of (1) the relative separation (or approach) of the two vessels (2) the rolling of W and (3) the yawing of W to be transferred to the wave engine on W.

First as regards V: (1) the transference of the pitching action ~~affords no difficulty~~ because the axle which passes across V turns to and fro ~~in its fixed bearings~~ in response to the pitching. ~~It is marked (1) in the diagram & is not otherwise indicated~~ The rod which causes it to turn is marked (1) in the diagram & the position of the centre of its Hook's joint is marked X as is supposed to lie outside V but the rest of the arrangement is not indicated.

The movements (2) & (3) are ~~shown~~ in the diagram


V
V2
V3
(1)
(2)
(3)
X

Two Hooks joints are attached, (we will suppose ~~say~~) to the sides of V, ~~and~~ so that their centres & that of the Hooks joint for (1) all lie in the same straight line and parallel to the axis of the vessel V. but in the Hooks joint for (2) the cheeks which are attached to the vessel are perpendicular to the rear ~~vertical~~ while in that for (3) they are parallel to the deck ~~horizontal~~. Short rods which are attached to ~~connected~~ with the other ends of the two joints and are connected with ~~att~~ the rod by which (1) is linked ~~connected~~ to the other vessel W, all pass through tubes, where they are prevented from slipping endlong ways. ~~These tubes are~~ A link crossing the tubes ~~are~~ parallel to the line of centres of the joints is attached loosely by a screw to each of ~~placed along~~ the tops & another link is similarly attached to ~~along~~ the bottoms of the tubes, as shewn in the drawing, so as to compell all 3 ~~arms~~ rods ~~external to the~~ to move in parallel positions. The rod 2 & the rod 3, will then move freely in a parallel direction to (1) & be governed wholly by it. The use of the tubes is to ~~overcome the diffic~~ allow a slight

f. 8r

movement of rotation of the rods which must occur ~~according to the well known principle of unequal angles of rotation when Hooke's joints being dissimilarly placed~~ owing to the dissimilarity of the positions of the cheeks of the joints, according to a well known theoretical principle. It will be observed that an up & down (rolling) movement through any angle of (1) will produce an equal angular ~~vertical~~ movement of the arm V_2 turning in fixed bearings round an axis parallel to that of the vessel & that a side to side (yawing) movement through any angle of (1) will produce an equal angular ~~horizontal~~ movement of the arm V_3 also turning in fixed bearings round an axis perpendicular to the deck of the vessel. We have already seen that a pitching movement through any angle produces an equal angular movement turning in fixed bearings round an axis ~~at right~~ perpendicular to the sides of the ship, it therefore follows that any movement of the vessel V whatever so far as it may be considered as compounded of these 3 primary movements will be resolved by this arrangement into its component parts & will be transferred to the vessel V, giving independent motion to 3 arms moving in fixed bearings on board that vessel. VI

As regards IV, the arrangement is as follows. The Hooke's joint by which the slide is connected with W is large & the rods ~~connected~~ attached to it are not solid but hollow tubes. A second Hooke's joint works centrically within ~~them~~, care being taken that the centres of the external & internal joints occupy the same position. The movements of the inner ~~joint~~ apparatus necessarily conform to those of the outer, as regards up & down & side to side ~~movem~~ actions, but they are quite independent as regards rotation. I therefore cause the slide to communicate a movement of rotation to the inner apparatus & by its means ~~to~~ to an ~~wheel~~ arm on W. There are ~~many~~ well known ~~alternative~~ methods by which the~~se~~ conversion of a sliding movement into a rotatory one may be effected, perhaps an ~~movement~~ arrangement like that of the so called 'Archimedean' hand-drill may prove in this case to be the most compact & otherwise suitable. The (2) & (3) movements are ~~effected~~ dealt with on exactly the same principle as they were in V. ~~the outer joint~~ but only one additional

~~Hooke's~~ joint is required, as the outer arrangement, for, say, (3) above mentioned, will serve for the other, say (2).

Having thus separated all the movements of the link into reciprocating actions of arms moving ~~some~~ in ~~fixed~~ bearings fixed to the solid frame work of either the ~~same~~ of one vessel or the other. I will suppose them to be transferred by link or wheel ~~wheel~~ work to arms all moving independently on the same axis. This is not a necessary supposition but it gives simplicity to the general conception. I will also suppose ~~[illegible]~~ ~~that the arcs through which they move are made unduly proportionate to the actual energy of the several movements,~~ to be of amplitudes ~~between~~ a ~~process to be effected~~ (partly by fixed arrangements & partly by adjustments made at the time according to the state of the sea. Thus if the average 'work' done in rolling is half of that done by pitching then the arc through which the arm connected with the

for

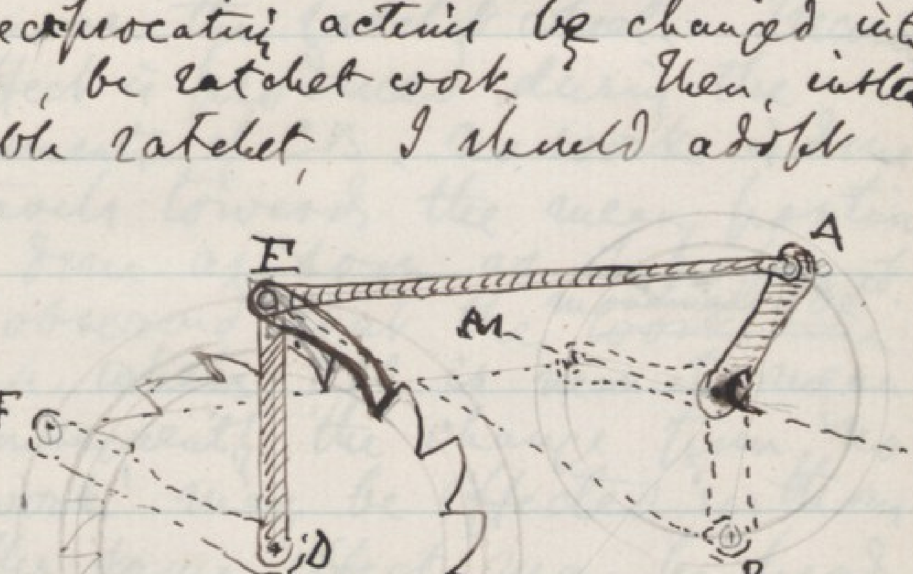
for facility of explanation, that the arcs through which the arms move to & fro are so regulated (partly by fixed gear and partly by adjustments made at the time, according to the state of the sea) to range ~~between~~ within 360°. Thus if the maximum ~~restricted~~ roll of the ship from one side to the other when restricted by the wave engine, ~~is~~ is reckoned at 30° ~~for a complete oscillation~~, then the arms would be so geared as to move through about 12 times the arc of the ~~Hooke joint~~ corresponding movement of the Hooke joint

~~× This being premised with the remark that the supposition made is only for the convenience of taking one out of many alternative ways~~

~~It now remains~~ We have next to convert these ~~irregular~~ reciprocating movements into ~~direct irregular~~ movements always acting in one direction and to do it in ~~such~~ a manner that shall ~~conduce~~ ~~give what we may call 'stability' to the~~ cause the ships to tend, as they are agitated to & fro to return to their mean ~~distance~~

amount

amount of separation & of parallelism to say nothing of a general tendency to right themselves. It is obvious that if no such contrivance be introduced the slide will be apt to be driven home and the yawing to ~~lead to~~ produce divergence of the courses of the two vessels. The principle on which I ~~use~~ obtain ~~this~~ the righting power where required, is by causing the wave engine to be worked by those movements alone which diverge from the mean position & not by those which return to it. Thus suppose the means by which the irregular reciprocating action be changed into circular motion, be ratchet work. Then instead of using a double ratchet, I should adopt this principle.



Let CA be the reciprocating arm which in each complete ~~to~~ and fro movement rotates through the mean position CM to CB and then back through CM to CB and let this arm be linked by AE to another arm DE as shewn in the diagram. Then ~~when~~ when CA travels towards CM or as the ship is recovering itself DE is pushed towards DF & the paul connected with DE slides over the teeth of a ratchet wheel centered at E without doing any work. But when CM is travelling towards CB the arm DE returns towards DE & the paul moves the ratchet wheel. Precisely the same effect is produced during the return movements of CB. no work is done while it travels towards the mean position but work is done as soon as it passes it. It will be observed that the movement of DE ~~work done~~ is very small ~~when~~ when CM is near its mean position consequently the change from 'no work' to 'work' may be effected without jar. The same effects may be produced ~~firs~~ by causing the pitch of the screw in the sliding movement (if a screw be used) to vary so that very small ~~the movement~~ gradation is caused by sliding near the mean position of the slide; secondly by applying to a double action detent a separate movement worked by a cam, that makes any arc less than one complete revolution for a single to or fro movement & which lifts ~~both~~ one of the detents when the slide is on one side of ~~returning to~~ its mean position and the other detent when it is on the other side.

In using the term ratchet I of course include apparatus like the well known nipping . . . . . . & should ~~prefer a~~ which is obviously preferable as being in principle a ratchet of an infinite number of teeth, silent in action & no less strong than a common ratchet.

Again, the conversion of reciprocating into circular motion may be effected not by ratchet work but by a water engine, in which the arm works the piston & the movement just described as governing the detents, would be employed ~~used~~ to govern the valves.

The next process is to combine the independent movements upon a single shaft, ~~which~~ the water

Engine

of which had as many cylinders as working arms would of course effect this - ~~attention~~ care being taken ~~that the water to be delivered by each piston bore under the same common pressure~~ to adapt the areas of the several pistons to the average work done by the ~~respective~~ respective arms & to regulate the length of the stroke from time to time according to the character of the ~~movement~~ movements as dependent on the varying ~~nature~~ quality of the waves & course of the ship. The several pistons would pump into a common receptacle (with ~~an~~ a compressed air chamber attached), whence the flow of water into another piston would work the machine.

If ratchet work be used (using the term in the general sense as above) - the several wheels in gear with the ratchet wheels might be connected to their common shaft through the intermedium of a coiled springs. Then the shaft would move under the combined influence of the strains of the springs and irregularity in action would be largely diminished.

It is also possible by epicyclic mechanism to add the separate movements together and considering that the ~~sum~~ joint effects of many irregular movements is less irregular than any one them separately it may be found that such ~~addition would~~ mechanism would conveniently & adequately replace the springs ~~on~~ ~~[illegible]~~ the many ~~It would also replace with appliances the many pistons above spoken of that are in direct connection with the arms~~. The principle of doing this is explained as follows:—

Let L M N be the three wheels in gear with the three independent ratchet wheels O P Q as required to give ~~the~~ another wheel R the sum of the movements O P & Q ~~[illegible]~~. The axis of movement of all the wheels is in the same straight line. L is fixed to its axle l, M to m, & N to n. At the end of l, between it & m, is a hook point, to the other side of which ~~an~~ rod L′ is fixed. ~~and L′ passes through a~~ and the similar arrangement is made as regards m & n.

L M N the 3 ratchet wheels all [smooth] on same axle & R the wheel to receive their combined movement

& let them be geared with $L' M' N' \& R'$ so that for each revolution of the several wheels $L' \& M'$ ~~that~~ the first & last of the series shall make ~~respectively~~ 2 revolutions, & the remainder 1 revolution respectively.

Rev^n of R' = 2 rev^n of N' + rev of ~~M~~ ~~[illegible]~~

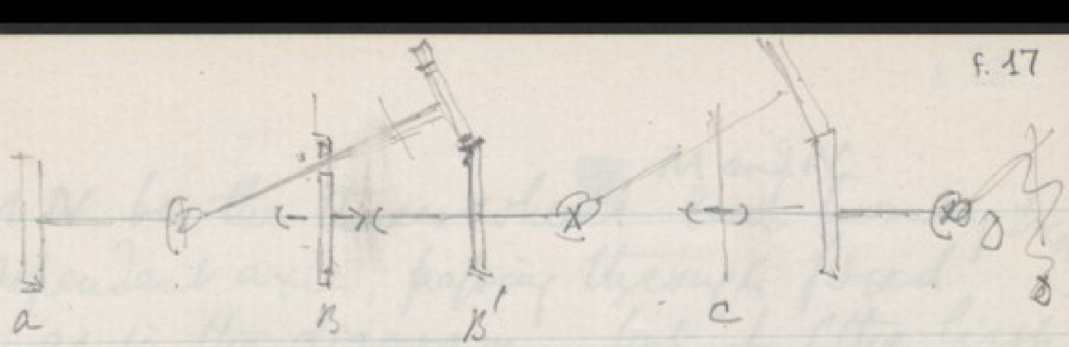
= ~~2 rev of N'~~

= ~~rev of M~~

= 2 rev^n of N' + 2 rev^n of M' + rev of L'

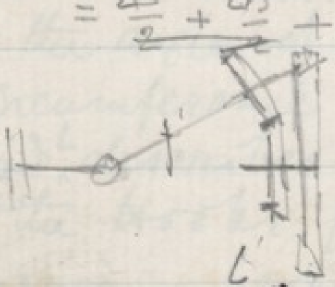
∴ 2 rev^n of R = 2 rev of N + 2 rev of M + 2 rev of L

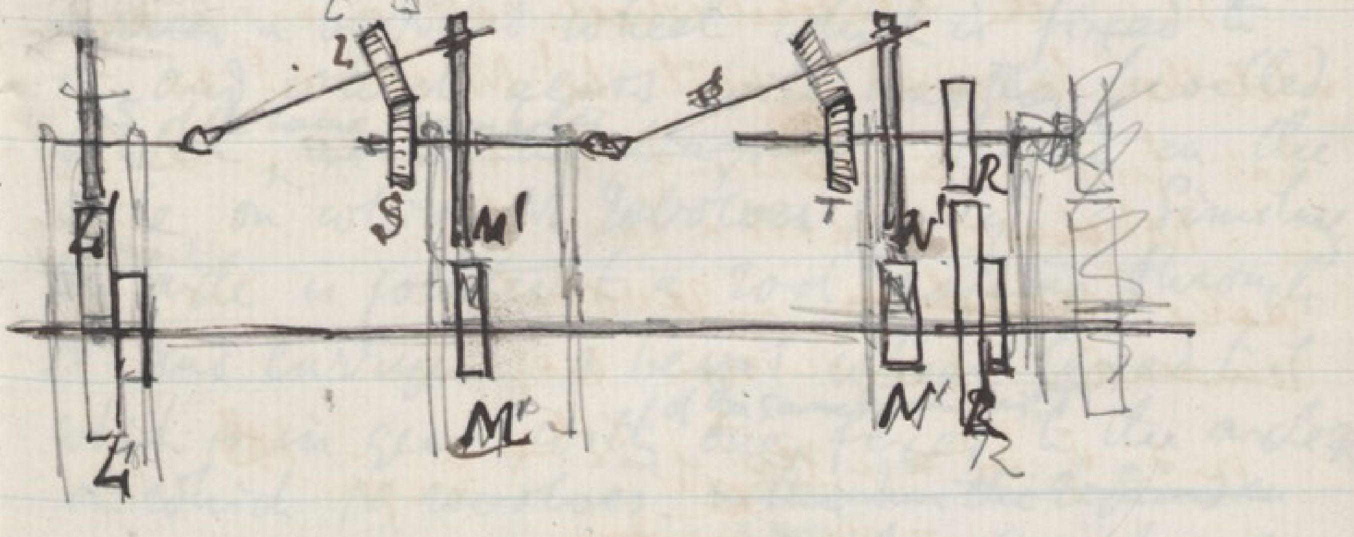
This is not strictly true [proportionately] [single rev^n or] the parts of [a] revolution but ~~quite~~ near enough for the present purpose.



$D = \frac{2C}{4} + B'$ $\qquad B' = \frac{2B}{4} + A$

$= \frac{2C}{2} + \frac{2B}{2} + A$

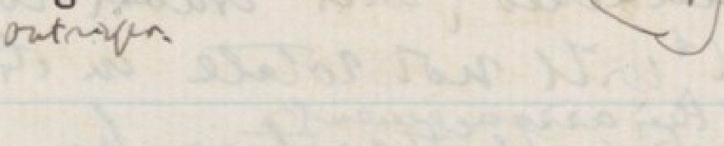




f. 18r

Let L M N be the three wheels M and N turning freely on an independent axle, passing through fixed bearings as in the diagram. but L (the first of the series) being fixed to the axle and so geared as to revolve with twice the velocity it would otherwise have. A rod L linked by a Hooks joint to the axle of L passes through M near its circumference so that when M rotates the rod L describes a cone of which the centre of the Hooks joint is the apex. This rod L carries a bevilled wheel which is fixed to it and which gears with another bevilled wheel of the same diameter fixed on the axle on which M revolves freely. Similarly this axle is jointed to a rod S passing through N and carrying a bevil wheel fixed to it which is in gear with one of the same diameter fixed to the axle on which N revolves.

On the rotation of N the rod S with its bevil wheel attached, will travel round N but the rod S will not rotate on its own axis. The effect of this arrangement will therefore be that of the or else a mere ball & socket joint or chain to the centre of buoyancy of the outrigger & [illegible]



well known 'Sun & planet wheel' & T will revolve twice. & for each revolution of S, (T will also revolve once) Therefore the revolutions of T = revolutions of S + 2 revolutions of N (This is not true with strictness but only approximately for fractions of revolutions uncorrected & near enough for practical purposes) Again each revolution of S = revolutions of L + twice revolutions of M ∴ therefore revns of N = twice revns of M + N + revns of L

If then L & N the first & last of the series be so geared as to convey only one half of the velocity they

(see last page opposite half)

To combine the following movements on one shaft viz Rolling of V relatively to link, pitching of V relatively to link, relative pitching of V & W & relative separation of V & W we require 3 Hooke's joints one inside the other instead of 2 as in ... & the innermost of them joints conveys the relative pitching of V & W. With a link of this kind all the important work performed by an outrigger relatively to a large vessel may be conveyed. The rolling being of little importance, the yawing not of need.

f. 19v

~~4~~a.

Although each of its internal movements is made upon 5 ~~[illegible]~~ bearings which permits motion only in one plane, relatively to those bearings.

arms oscillating in fixed bearings on board of

~~as many~~ (if required ~~as~~)

(3)

To prevent the jar of the slide in the link, from being repeatedly driven home I use a contrivance by which ~~it is caused~~ in its to & fro action it always tends to restore itself to its mean position the principle ~~[illegible]~~ involved is that the slide does work only when deviating from its the mean position and not when ~~is~~ returning to it.

To sum up. (1) I ~~first~~ link one body floating or suspended in water to a vessel or ~~another~~ ~~similar~~ floating body or another ~~or to a stationary object~~ by a ~~The link I use has five sole joints and one slide~~ link which the joints permitting perfect freedom of movement within wide limits ~~although no~~. (2) I transfer the several reciprocating movements of the link words six in number to the objects linked together as many as ~~half~~ 3 of 4 of them to one object & the remainder if required to the other; (3) I keep ~~prevent~~ the to & fro ~~action of the slide in the link to~~ near its mean position in the ~~middle of the~~ link in order to prevent the jar of the slide ~~it~~ when at the being driven home & by causing it ~~the slide~~ to do work when deviating from ~~its mean position, but not when returning to it~~ and I employ this same ~~action~~ principle as a ~~as a~~ righting agency to such other of the movements of the link as may in ~~any~~ special cases seem to require it. (4) I convert the reciprocating movements of the arms into circular movements in one direction and (5) I combine ~~sum~~ their effects upon a single shaft.

f. 24

Formula

Energy in unit of wave water

$= 0.304 \times$ ~~diameter~~ $\left\{ \frac{\text{height of wave in feet}}{\text{periodic time in sec.}} \right\}^2$ in foot pounds

~~∴ in 1 ton of wave water~~
~~$(= 20 \times 112^{lb} = 2240^{lb})$ the ~~formula~~~~
~~energy in ~~for~~ horse power per ton~~

~~$1.25 \times \left\{ \frac{\text{height of wave}}{\text{periodic time}} \right\}^2$~~

2240
.306
13440
00000
6720
550) 685.440 (1.25
550
1354
1100
2544

1 ton of wave water $= 20 \times 112^{lb} = 2240^{lb}$
550 foot pounds = 1 horse power
∴ the energy of 1 ton wave water $= \frac{2240}{550} \times 0.304 \{ \}^2$

$\frac{2240}{550} \times 0.304 = 1.25$

∴ energy of horse power per ton

$= 1.25 \times \left\{ \frac{\text{height of wave in feet}}{\text{periodic time in sec.}} \right\}^2$

= 1.25 when height of wave in feet = period. time in secs

f. 25r

Period v length of waves in deep water

waves period = $\frac{1}{n}$th of a sec then its length $\lambda = \frac{g}{2\pi n^2}$

write m for $\frac{1}{n}$ — mth of a sec $\lambda = \frac{g}{2\pi} \cdot m^2$

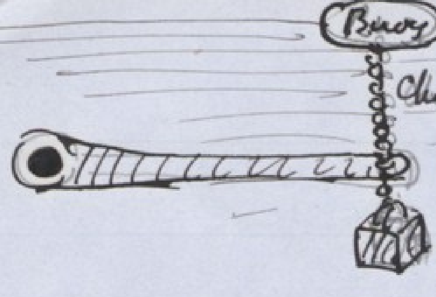
f. 25v

If the period of wave in seconds
= height of wave² in feet then
the energy of a layer of its surface
water) ~~= 1.3 horse power per ton~~
(in ~~seconds~~ 1 1/4 horse power per ton

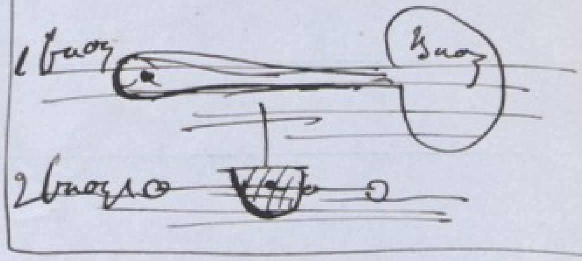
when the height is double the period in
seconds the energy = 5 horse power per t

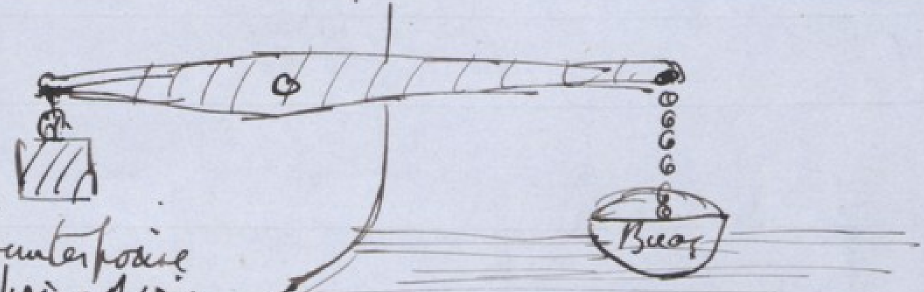
Wave Energy – measured in Horse Power per ton of surface water

Length of wave – feet	5	20	46	82	128	184	251	328
Period of wave Sec	1	2	3	4	5	6	7	8
Heights of wave ft.								
1	1.2	0.3	0.1	0.1	0.0	0.0	0.0	0.0
2	5.0	1.3	0.6	0.3	0.2	0.1	0.1	0.1
3	11.3	2.8	1.3	0.7	0.5	0.3	0.2	0.2
4		5.0	2.2	1.3	0.8	0.6	0.4	0.3
5		7.8	3.5	2.0	1.3	0.9	0.6	0.5
6		11.3	5.0	2.8	1.8	1.3	0.9	0.7
7		15.3	6.8	3.8	2.5	1.7	1.3	1.0
8			8.9	5.0	3.2	2.2	1.6	1.3
9			11.3	6.3	4.1	2.8	2.1	1.6
10			13.9	7.8	5.0	3.5	2.6	2.0
11				9.5	6.1	4.2	3.1	2.4
12				11.3	7.2	5.0	3.7	2.8



Simplest of all

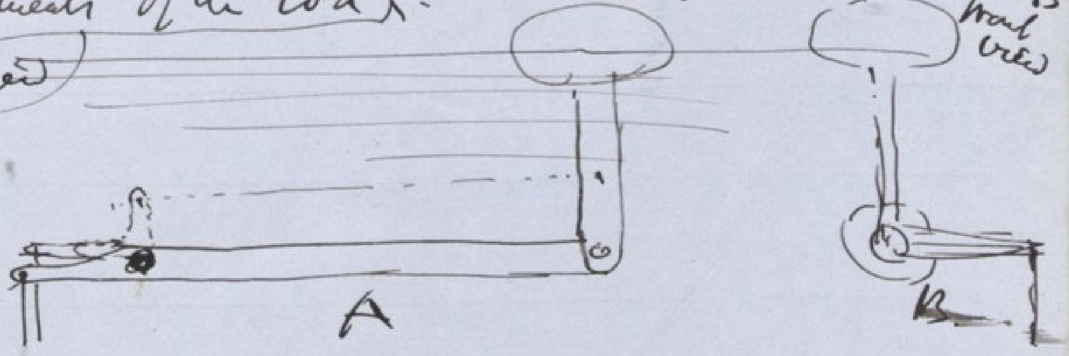




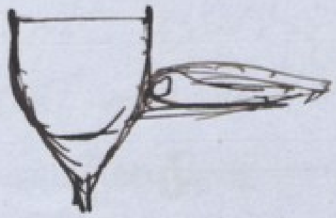
Counterpoise
Spring of iron
Spring of compressed air

As before, but with rod instead of chain & utilising the movements of the rod. also from side to side B front view

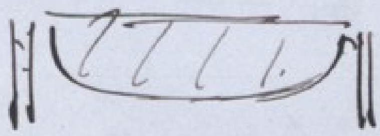
(to & fro
A. side view)



center boards

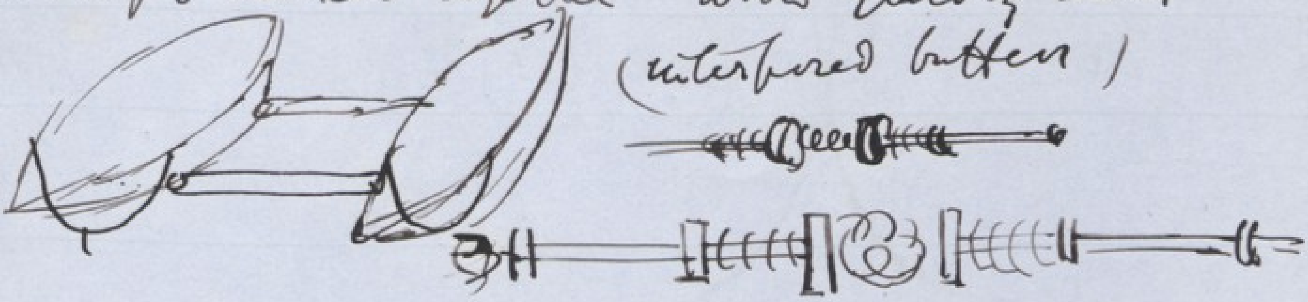


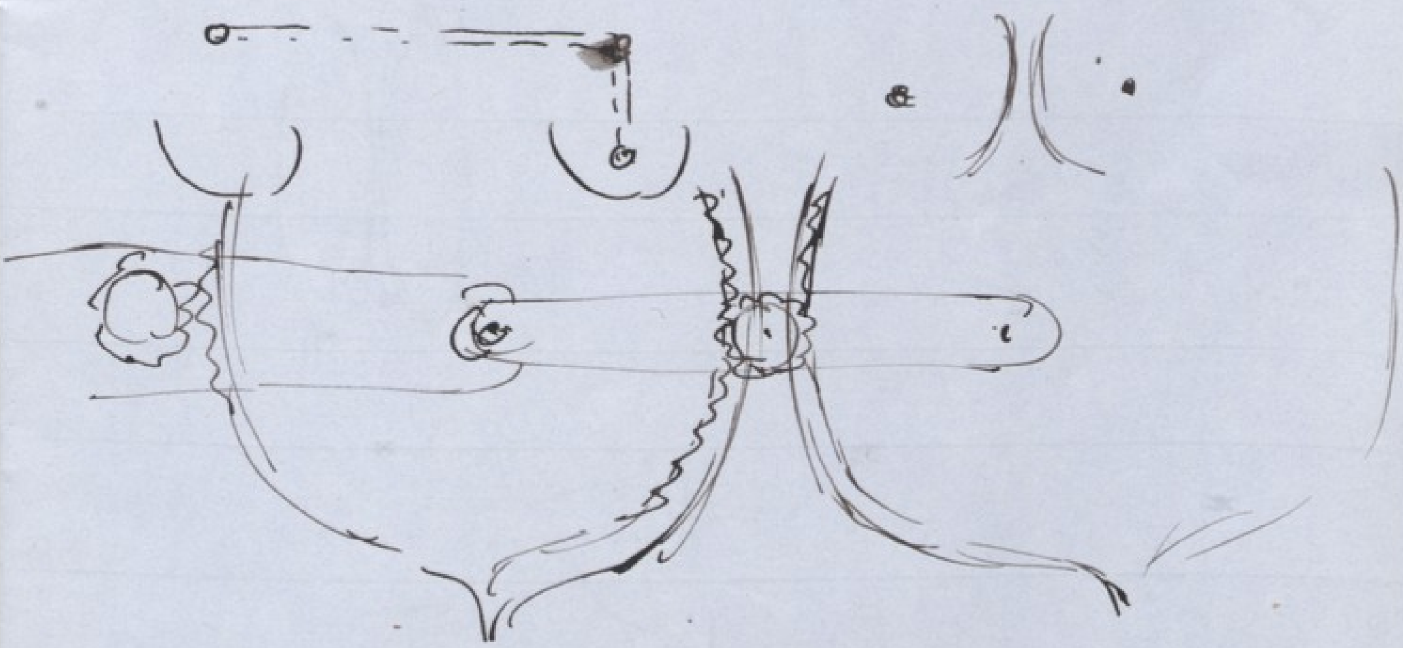
side keel.



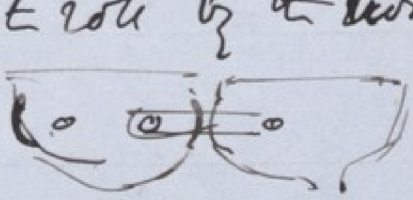
lea boards

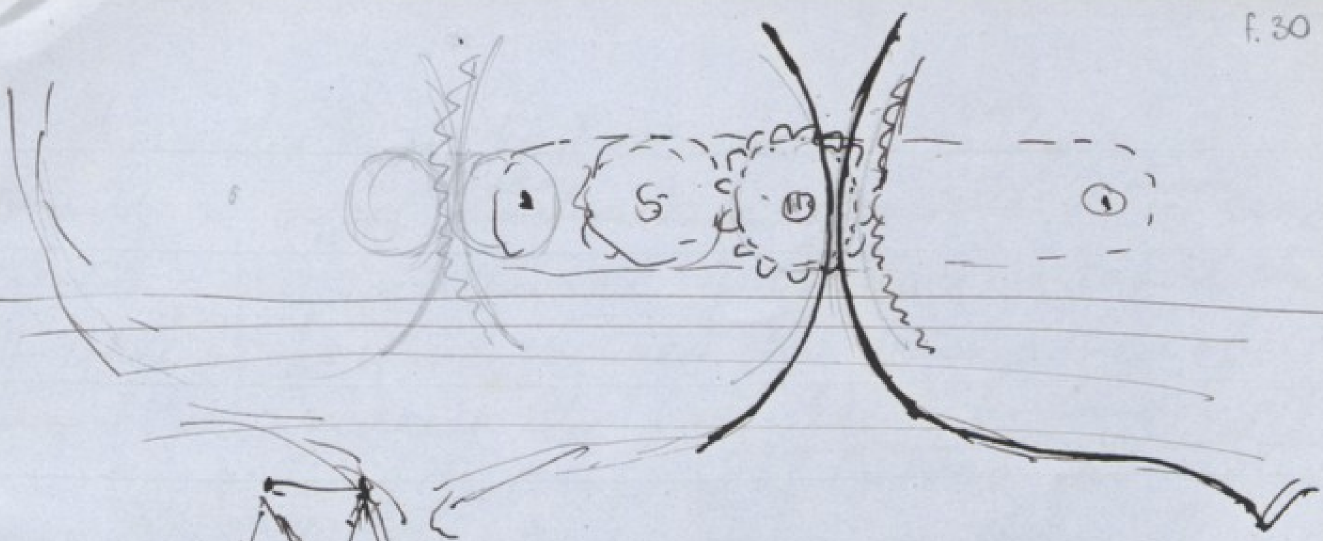
2 or 3 Ships Worked together with girding links (interfered buttons)

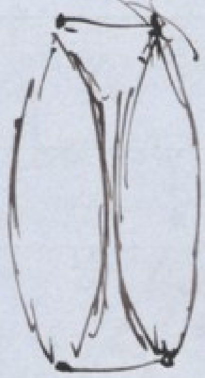


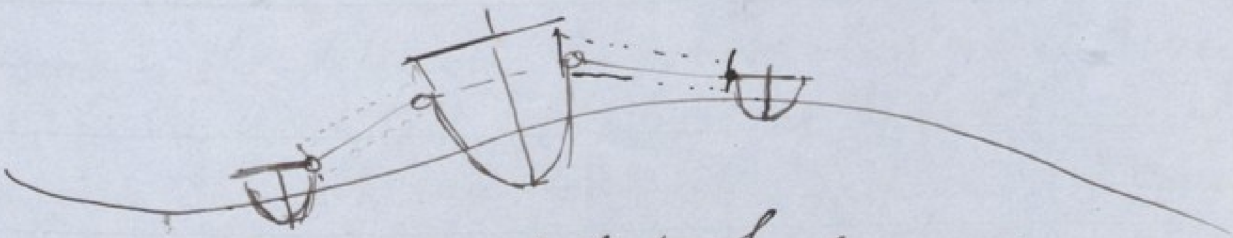


? better let the centres on which the drinks turn be some distance from the centres of rolling then the ships will be made to roll by the horizontal thrusts









The machinery is aboard of th the two pontoons – none on the middle ship. The pontoons must have so much stability that no thrust can cause them to capsize.

Those who have in rough weather had occasion to ~~embark~~ got on board a vessel at sea ~~anchored in a roadstead~~, ~~in rough weather~~ are well aware of the large & rapid changes of relative position between the boat & the vessel. ~~The~~ At one moment the boat has to be fended off from the sides of the companion ladder against which it is violently dashed, at another, ~~the~~ it is lying ~~far~~ moving back ~~beneath~~ its lowermost steps. Up ordinary activity & ~~the~~ in a person unaccustomed presence of mind are required to ~~jump at~~ seize the exact moment ~~at~~ when it is possible to jump on to the ladder without ~~risk of~~ accident. Even if the ~~vessel be~~ waves be so short compared to the length of the vessel that she rests ~~lying steadily~~ in perfect steadiness while the boat is tossing about, ~~so what compared to~~ the difficulty of embarkation is still very great. For the rise & fall of the boat is 4 feet in moderately rough weather in a roadstead like Spithead (of course it is much more in the open sea) and ~~the~~ it will be repeated perhaps 12 times in the minute. It is clear that this energy might be made to do work: if the boat were secured to the end of an arm, moving vertically up and down like a pump handle that handle might be connected with ~~machinery~~ suitable mechanism & caused to perform useful work. Again, those who have been in a ship in a storm, ~~know~~ know well the violence with

f. 32

which the rudder is swung by the waves. It is so great that notwithstanding the ~~multiplying~~ tackle which restrains it & which is virtually the same thing as governing it by a lever ~~the~~ & notwithstanding the combined efforts of many sailors, the rudder, which offers but little surface to the sea occasionally becomes unmanageable, in short the forces that dashes ~~it~~ from side to side exceed all the available restraining forces, although these are very great. Here ~~the~~ also is energy running to waste, ~~a hinged keel a seaboard~~ and we see, that a hinged keel or sea board as it is is washed from side to side might be connected with suitable machinery & caused to perform useful work.

The amount of energy in waves, in rough weather is enormous. Let us to simplify our enquiries ~~ha~~ as to its available amount, begin by supposing a case, analogous to my first example ~~the~~ where a small drawing boat whose length is small ~~[illegible]~~ compared to that of the waves is tossed about, in the neighbourhood of a steady object as a rock or a large ship. In this case the energy in the boat ~~is sensibly that of the water which it displaces~~ being is sensibly the same as that ~~the energy~~ of a layer of surface water of the same weight ~~this or case~~ may be calculated by the ordinary formulae. I give a table in which I have calculated the number

f. 33

of horse power per ton of surface water & therefore ~~for~~ within inconsiderable deviations, per tonnage of the boat (~~the boat being~~ small in draught & short compared to the ~~length of the~~ waves) which is supposed to be

Insert Table.

It will be seen, that in moderately rough weather with short seas such as waves 4 ft high from trough to crest & 82 feet long ~~an force~~ an energy of 1.3 Horse Power per ton exists in the wave. That in rougher weather as waves 5 ft high & the same length of 82 feet the Energy rises to 2 Horse Power per ton while in storms it may exceed 5 Horse Power per ton. This enormous force is the accumulated result of wind action on the ~~waves~~ sea for many previous hours ~~and through ea~~ It is a store from which each ship may exhaust all ~~that~~ in its immediate neighbourhood without sensibly diminishing the ~~remainder~~ continuance of the supply, a long floating breakwater would no doubt wholly exhaust it in internal strains & would ~~leave~~ create calm ~~water~~ to its leeward, and even a solitary ship leaves a wake behind her ~~an obvious wake~~ but a ship is continually buffeting among fresh

(Such a mere dot in the ocean that she is

f. 34

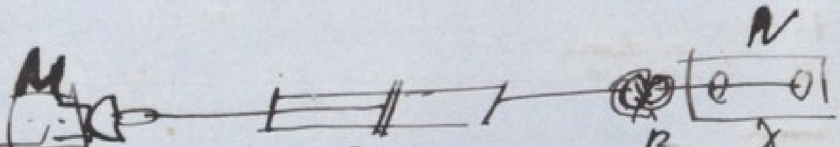
waves whose violence is not sensibly diminished by the more or less complete extinction of their predecessors. ~~The surface of the sea is so enormously in excess larger than~~ Ships are such mere dots in the ocean that the energy which each of them could abstract from its waves

The force by which a rudder is dashed from side to side in a storm is ~~due to more complex~~ only a part of the total energy of the wave through which it passes, so also is that by which a hinged keel would be ~~urged~~ affected. The latter is due to the fact that a flat body tends to float parallel to the wave surface but a vertical plane does not tend to place itself ~~so~~ at right angles to that surface. On the contrary, when it is free to move it ~~assumes a position~~ inclines towards the crest of the nearest wave consequently the angle between the plane of its ~~path~~ flat bottom and that of its leaboard tends ~~is~~ constantly ~~tends~~ to vary.

~~Into~~ These latter partial results of wave energy I do not propose to dwell but ~~rather~~ instead to take the case ~~of~~ in which as much energy as possible is abstracted because I believe it to be practically the most important & because the more complicated mechanical arrangements with which I shall have to deal, embrace all that would be necessary for more limited applications

The case I propose to consider, is that of two vessels linked together by a beam, of perhaps 3 or 4 times the breadth of either of them, and all their movements so connected with mechanism that every tendency to heave, roll, pitch, yaw or make lateral movement shall be 'translated' into rotation of the screw.

It will be found ~~that~~ if the connecting link be of the annexed form



A & B two Hooke's joints 4 motions between them C a slide. D an ~~horizontal axis~~ revolving axis ~~that~~ the movements of the ~~two~~ ships M & N are perfectly free within the limits of the slide C. & that they can be moved in every direction. The connection is even more free, than if it ~~consisted of a~~ were a cord because of the free slide at C. This is the link I propose to adopt & I will shew how all its separate movements may be caused to accumulate on the screw.

F. 35v

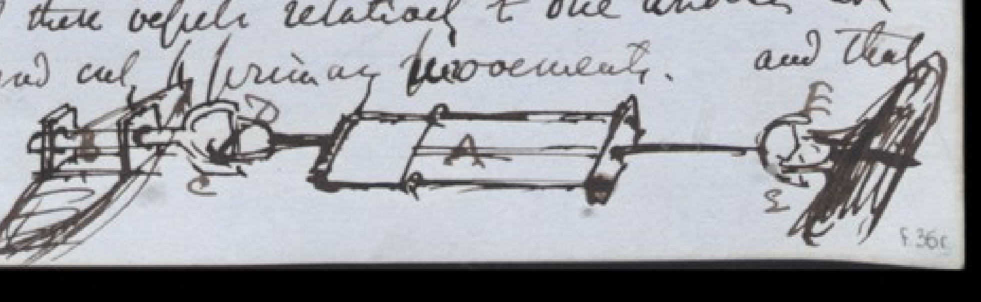
The object of the wave engine is to cause one part of the violence of these relative motions to perform useful work

The object of the wave engine is to extract useful work out of the force which is ordinarily wasted in the violence of their relative movements and

and the excess of energy wasted shown in the motion of bodies rolling about independently over that when they are linked together by my machine is the supply of energy which works the machine

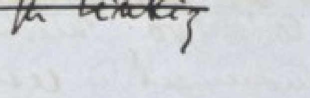
The fund of power by which the wave engine is worked can be estimated by the difference between the sum of the movements of the two bodies independently agitated by the waves and their diminished violence when these bodies are linked together by the machine a wave engine – that is a machine by which waves may be made to perform useful work.

It is well known in ~~[illegible]~~ motion in various directions, to bodies
that the action of ~~the~~ waves ~~[illegible]~~ floating or suspended ~~bodies~~ in the water
~~is as well known~~ to move ~~is well known~~. Also it is
well known, that two such bodies, even though they are near together
~~are affected differently at each on the same instant of time~~ by the passage of the waves,
~~and~~ have ~~not only~~ relative ~~motion~~, ~~to one another for they~~
~~simultaneous~~ ~~are urged at each instant of time by different forces & have~~ considerable
considerable relative motion ~~motion~~ to one another (these depending on [illegible]) The object of my wave [illegible]
Engine is to ~~utilize~~ these motions ~~due to the~~ waves, to perform
work & machinery by the energy so [illegible] ~~being so imparted~~ one body which is free
~~useful work~~ I think ~~that a floating body~~
wasted in useless movement
to move in one or more directions whether immersed in ~~[illegible]~~ agitated water
either to a fixed ~~body~~ object or to another immersed body and
I cause the movements of the connecting link to ~~[illegible]~~ govern the motion.
~~powers~~ of my machine. Then to take one the simplest of ~~[illegible]~~ cases, suppose
a buoy fastened to the end of a pump handle the pump being
on shore, or else on board another vessel then the movement ~~[illegible]~~ would work ~~that pump~~ the pump
So a hinged keel or leaboard ~~[illegible]~~ swinging to & fro by the [illegible] of the waves might be similarly
connected with a pump or other machine. But in these cases, where movement is restricted to
~~[illegible]~~ only a small part of the energy contained in the [illegible] But
can be utilized the remainder between wasted in strain ~~[illegible]~~
a machine ~~[illegible]~~ movements of the wave [illegible]
~~direction~~ ~~[illegible]~~ on the following principles. ~~[illegible]~~ to take the ~~most complex~~
~~Every body is susceptible of three movements and six only~~ – they are arrangement
~~rotation about its three principal axes & transference along them~~
by which the most complex set of movements can be worked the objects
~~case (which [illegible] simpler ones)~~ by ~~[illegible]~~ supporting ~~two vessels~~
linked together to be two vessels. It will be found that all
possible movements of these vessels relatively to one another are
combinations of 6 and only 6 primary movements. and that
a link consisting



The case I will specially consider is where each vessel shall be urged by 3 of these movements the one vessel being affected by (1)A its own ~~(1)~~ rolling & heaving (2A its own yawing relatively to the connecting link & (3A also relatively to the link the relative pitching & tossing of the 2 vessels. The other vessel being affected by ~~(1)~~ its own ~~rolling & heaving~~ (1B & (2B as above described & (3B by the Relative twisting to & fro ~~together or apart~~ of the vessels. ~~This case is~~ (many limited in their freedom of motion) simpler Arrangements of course are included in this case I propose to consider & need not be especially alluded to ~~which~~ As to more complex arrangements I will subsequently describe one in which A_1 A_2 A_3 and B_3 may ~~are~~ all be brought to bear on the same vessel. ~~which is of use in chasing on 2 vessels each containing such a link~~ ~~may~~ is completed ~~provided for linking~~

rolling r
pitching p
yawing y

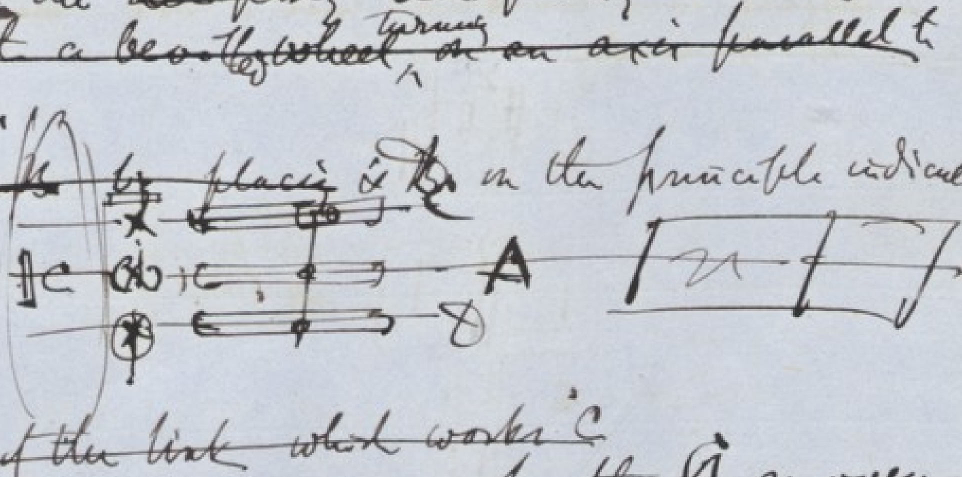


of parts, like those represented in the diagram. When A is rotated B slides, ~~without~~ C & D, are the 2 movements in one Hooke's joint & E & F those in the other, permits perfect freedom of movement ~~(within the limits of the slide & of those of the Hooke's joints)~~ to the two ships, A allowing relative pitching & tossing, B separation & approach, C rolling & heaving of one ship, D the yawing of the same ship, E rolling & heaving of the other ship & F its yawing.

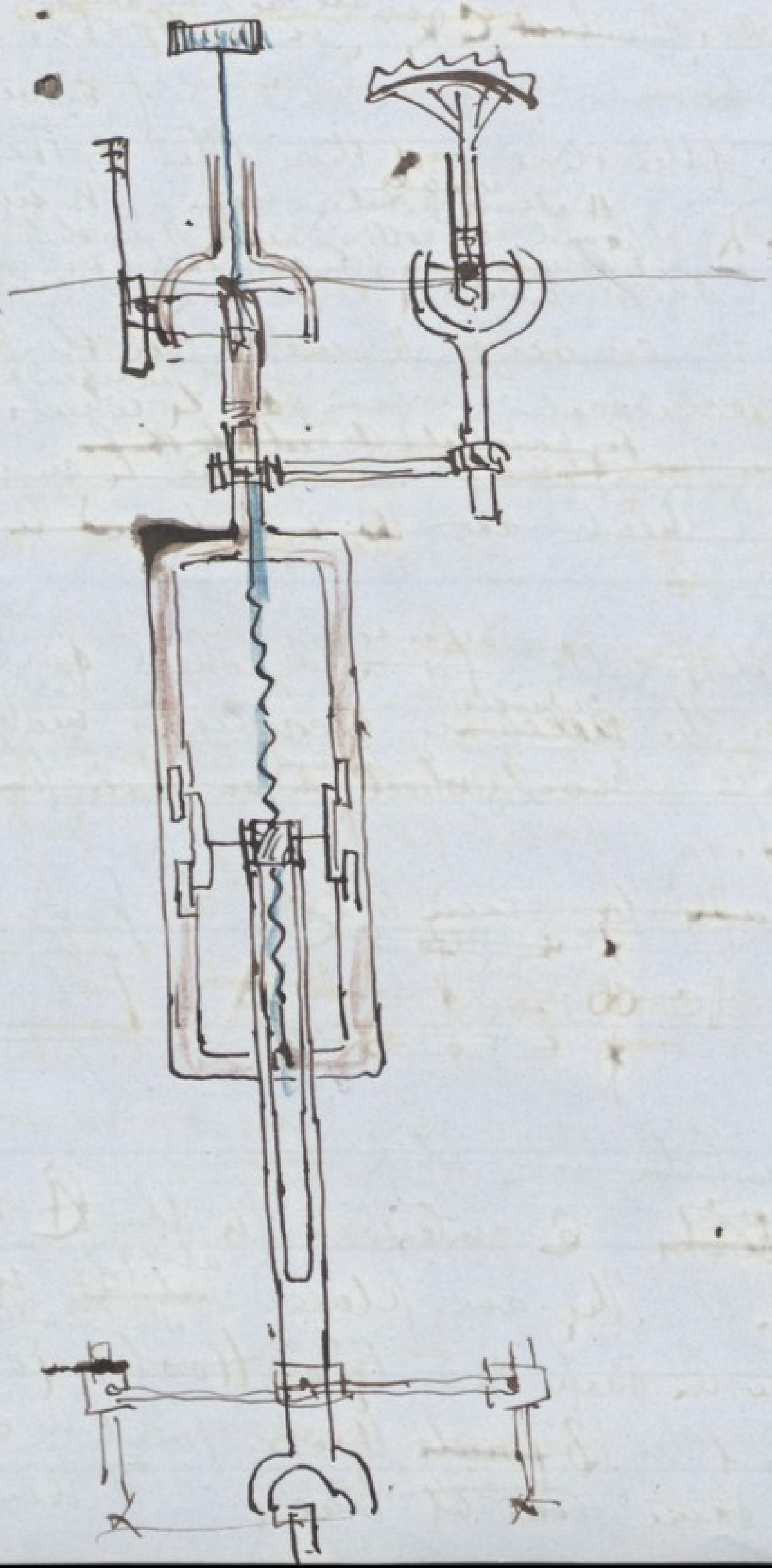
I first propose to show how 4 of these movements viz ABCD may be separately conveyed to one of the ships & there made to cause reciprocating action in 4 independent wheels ~~which may be centered on the same axis parallel to the keel of the ship. The 4 movements in question of which I speak are the 2 contained in one of the Hoo A B C & D.~~

A affords no difficulty because a wheel fixed on its extremity has the required reciprocating motion ~~& it can of course be geared with a bevelled wheel turning on an axis parallel to the keel of the ship.~~

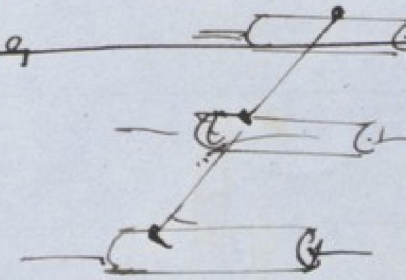
I deal with ~~A & B by placing it~~ B on the principle indicated with figure



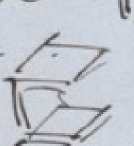
~~On c, the neck of the link which works C~~
I have 2 rods C intended for the C movement along sides of A & D for the D. They are placed ~~at the~~ along sides of A which I will call a & b respectively & are jointed to the ship each by a Hooke's joint, & the centres of the 3 ~~joints~~ Hooke's joints (c d d' & e) are all in the same straight line. I then connect



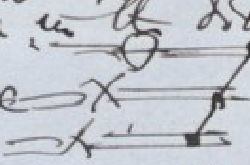
a b & c so that however c be moved they shall always be parallel ~~this is done by passing them through tubes~~ ~~which allow~~



If all the 3 joints were ~~similarly~~ placed they could be effected by a cross rod a b c parallel to â b̂ ĉ screwed to a b c & ~~jointed~~ as shown in the diagram, directly ~~to a b & c~~

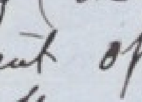


~~but they cannot be seen~~

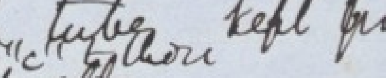


but as in my ~~appx~~ machine the 3 joints ~~are~~ are not similarly placed, it is therefore necessary (on account of a well known property in Hooke's joint of unequal velocity of rotation of ~~one~~ its limbs in different positions) to pass â b̂ & c through tubes kept from sliding & to screw ~~link~~ the cross rod a'' b'' c'' to those tubes ~~together~~

Now I place ~~a~~ the Hooke's joint a'



~~so that~~ b' dissimilar in position. The axis ~~vertical~~ its cheeks which are fixed to d' ~~against~~ the ship ~~along with the horizontal side~~. in a plane perpendicular to its axis & those of b' are



parallel to its deck. Consequently when c is lifted or depressed carrying with it a & b the axle of a which ~~is fixed in position~~ revolves in fixed horizontal bearings is ~~done~~ turned while when c is moved forwards or backwards the axle of b which revolves in fixed vertical bearings is turned. There

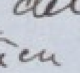
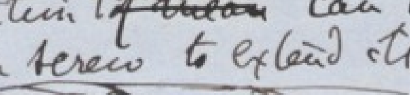
axles ~~may be geared to~~ have the required independent
reciprocating axle.

Lastly as regards the sliding movement B. I ~~cause it to produce introduce an integ~~ make a^x tubular & the point a' large & introduce b through the tube of a and make the shorter point b' work inside the ring of a', ~~&~~ ~~cause~~ adjusted to the same center then b' turns quite independently of a'. I cause the sliding motion off the back to give rotation to b'! ~~preferring subject to further experiment out of many possible a more or less~~ This can effected in many ways well known ~~ways~~ to mechanicians as by a screw of very high pitch worked with a nut like the well known hand drills or by the pushing & pulling out of ~~compressing~~ a system of ~~dia~~ crossed links work on the principle of the well known 'lazy back tongs' when the first link is attached to ~~the~~ a "bc" to an horizontal wheel turned on an axis attached to the ... a gear with a vertical wheel attached to B. Then are also other methods ~~with~~ as wheel & rack work & wheel & chain which may ~~have~~ be found to have merits in practice & which I may after experiment, prefer.

Having thus separated the 4 movements A B C & D & caused independent ~~separate~~ wheels to answer ~~to move to fro by theirs~~ to each of them I will suppose for facility of conception what is not essential in practice that these movements are transferred by ordinary gearing to 4 wheels ~~turning~~ on the same axes, namely one parallel to the keel of the ship & that the rate of movement is so arranged ~~that~~ the free extreme to & fro movement of the ship causes about one ~~complete~~ rotation of the wheel to & fro through a complete arc.

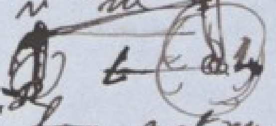
The next point is to convert this irregular reciprocating motion into

~~continuous~~ ~~rectilinear~~ circular (possibly rectilinear) motion in one direction only. This is readily effected for small machines such as boats might use by double detent, & ratchet wheel, or in larger machines by pumping with a double acting pump. I presume water or other fluid, with a chamber of compressed air would be a strong more serviceable than air or other gas. & I also presume ~~it~~ would be better to use a separate engine than to inject compressed air into the boiler of a high pressure steam engine.

There is ~~one~~ an important matter to provide for in the case of the B separating movement ~~& perhaps also in the D (yawing) movement~~ ~~[illegible]~~ namely that the machine should ~~not~~ do work only when the ship is deviating from its mean position & not when returning to it. in this ~~way~~ the to & fro work of the waves will always tend to bring the ship to its mean position, ~~for it will~~ ~~right it~~ more ~~readily~~ quickly than ~~This is easily effected~~ This is ~~effected~~ [illegible] raised by the detents or open the valve at the proper time. the other and prevent ~~not~~ allow the slide ~~from~~ striking home. ~~hardly necessary to describe how the detents~~ if ratchet ~~work may be used may be raised at the right time because~~ ~~it is obvious effected~~ by ~~[illegible]~~ these movements separated you see that by, It is easy to raise the detents or open a valve at the proper time by the action of a cam wheel which moves through any arc less than one complete rotation for each to & fro movement of the ship.  and fig 27 if the sliding movement be turned into a rotating one by ~~on the~~ the principle of the so-called Archimedean hand-drill the velocity of rotation about the mean position of the slide ~~[illegible]~~ can be made to cease by causing the pitch of the screw to extend itself for a short distance into a straight line 

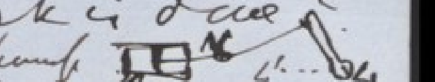
f. 41ar

Or on the other hand if it be found preferable to treat the two 1 & 2 in combination they may be effected on the principle

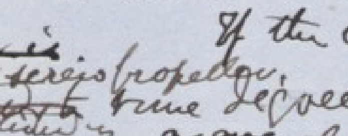


is so geared with the fusing reciprocating movement of the arm LL rotates less than 360 × better between 90° & 270° × in each to & fro action. M is a rod jointed both to L & to the paul bearer N, whose movement works the ratchet wheel R in one direction only. L L corresponds to the mean position of the slide. As LL moves towards the position to LL the pusher N & does work turns the ratchet wheel. Having passed the mean position the pull back N & the ratchet pauls freely slide over the ratchet wheel & no work is done.

This action is obviously applicable to a single action pump which might directly work ordinary hydraulic engine on the principle of a turbine



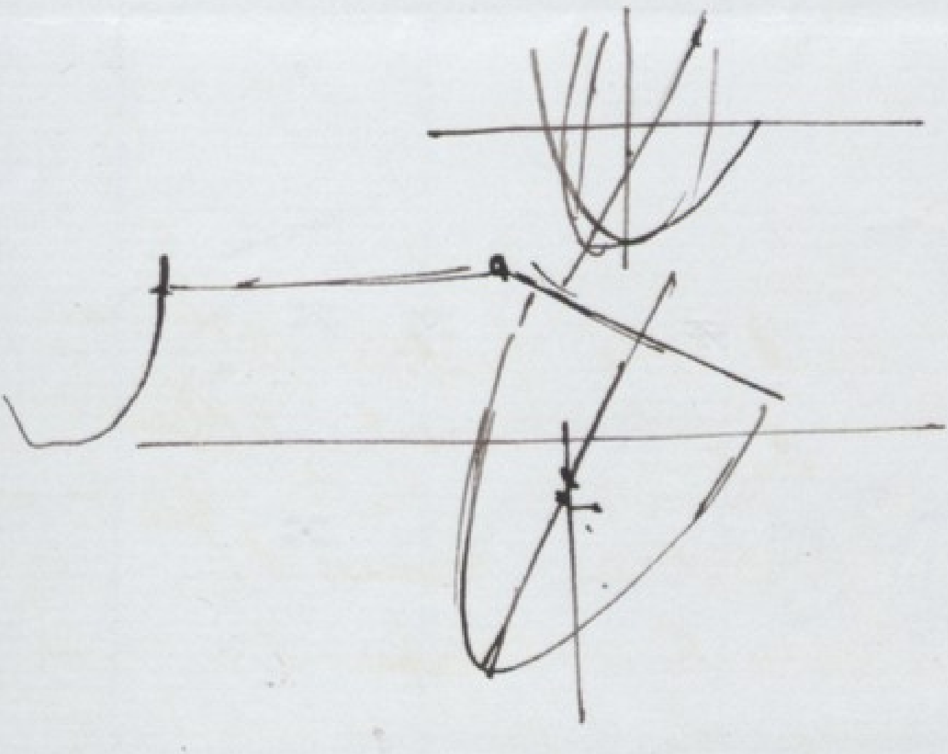
We are now supposed to have obtained the effects as regards the ratchet appliances, rails of desired on the same axes four independent wheels all moving irregularly and independently in the same direction but that all moving in the same direction. It remains to combine their movements on a single axis that of the screw propeller. If the wheels be geared to the axes that does the required work this would be effected to some degree & more so if the and better if the wheels were as are the ... wheels of a watch, secured each to their own axle through the intermedium of a coiled spring. that if one It is also easy by an epicyclic arrangement to add all the movements together. Thus let one wheel A rotate a limb S of a Hooke's joint, on the further limb of which is a bevelled wheel S' in gear with another T revolving round an axis lying in the prolongation of S. Also let a second wheel B cause the arm which carries S' to move round T without rotating S. Then on well known Epicyclic principles the independent movements of A & B will be added

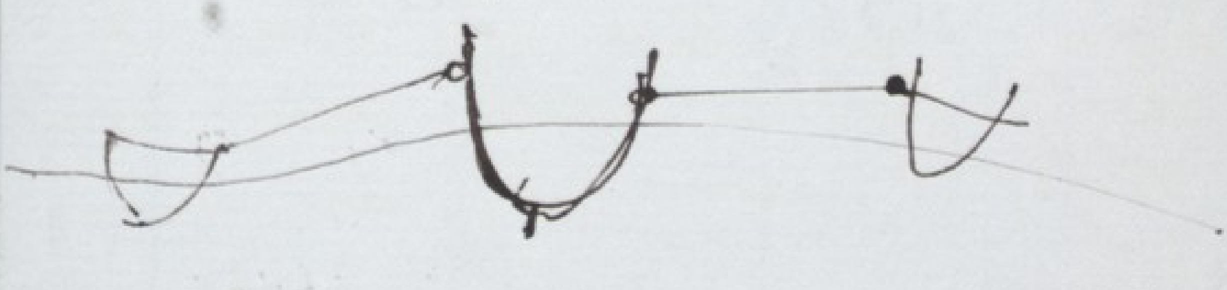


with solid joints and admitting of motion round one axis only

. & ~~I intend this principle~~ of making the action of the engine tend to ~~increase the~~ st right the ship to such ~~the yawing movement & to such [illegible] as may be convenient~~ ~~all the~~ other the movements ~~(so far~~ as ~~such~~ extension may be found in practice to require it).

f. 41 b





Length of wave	5	20	46	82	128	184	251	328
		Period in secs						
height of wave	1	2	3	4	5	6	7	8
1	1.25	0.31	0.14	0.08	0.04	0.03	0.03	0.02
2	5.00	1.25	0.55	0.31	0.20	0.14	0.10	0.08
3	11.25	2.81	1.25	0.70	0.45	0.31	0.23	0.18
4		[illegible]	2.22	1.25	0.80	0.55	0.41	0.31
5		7.81	3.47	1.95	1.25	0.87	0.64	0.49
6		11.25	5.00	2.86	1.80	1.25	0.92	0.70
7		15.32	6.81	3.83	2.45	1.70	1.25	0.96
8			8.88	5.00	3.20	2.20	1.64	1.25
9			11.25	6.30	4.05	2.79	2.07	1.57
10			13.88	7.80	5.00	3.48	2.56	1.96
11				9.45	6.05	4.20	3.09	2.36
12				11.25	7.20	5.00	3.68	2.80
13								
14							5.00	
15								
20								
25								
30								
35								
40								

f. 42

combined in T. This process may be repeated ~~with~~ making T take the place of A and putting C for B then in T_1 are combined A B & C & ~~so on~~ similarly for D. Thus all the independent movements are combined and ~~their action of may be~~ made either with or without the intermedium of a coiled spring (for the purpose of destroying the irregularity of movement) may be [illegible] put in gear with the screw propeller.

To sum up. I first link any body floating or suspended in water to another similar body or to a ~~fixed~~ object & I shew how the links may be constructed so as to give perfect freedom of motion within wide limits. Then I take the separate reciprocating movements of the links work in number & transfer them to wheels or arms each oscillating independently in fixed bearings ~~gearing~~ [illegible] on ship board or on the stationary ~~fixed~~ object as the case may be. Then I provide separately for the to & fro action by driving the slide home by making the slide do work when deviating from its mean position & not when returning to it. Then I convert the independent irregular reciprocating actions into independent irregular movements all in one direction. Then I combine these independent irregular motions upon one shaft & ~~[illegible]~~ moving with comparative regularity.

In each HP wave energy of a raft

× $\frac{4}{9}$ the most useful result × $\frac{3}{4}$ the loss of power by machinery

= $\frac{1}{3}$ net gain

$\frac{1}{3} \times 1.25 = 0.42$

~~[illegible]~~ or nearly $\frac{1}{2}$ HP per ton when period of wave in secs = height in feet.

force of a man = $\frac{1}{8}$th HP for weight of 150 lbs

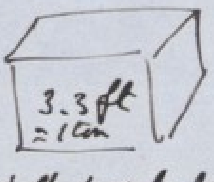
112	8 men –	1 HP	— — 1200
20	12 –	$1\frac{1}{2}$ HP	1800
2240	15	$1\frac{7}{8}$ HP	2200 = 1 ton

or force of a man = nearly 2 HP per ton.

1 ton displacement = $\frac{2240 \text{ (lbs in ton)}}{64 \text{ (lbs in cub ft)}}$ in cub feet = 3.3 ft cube of water

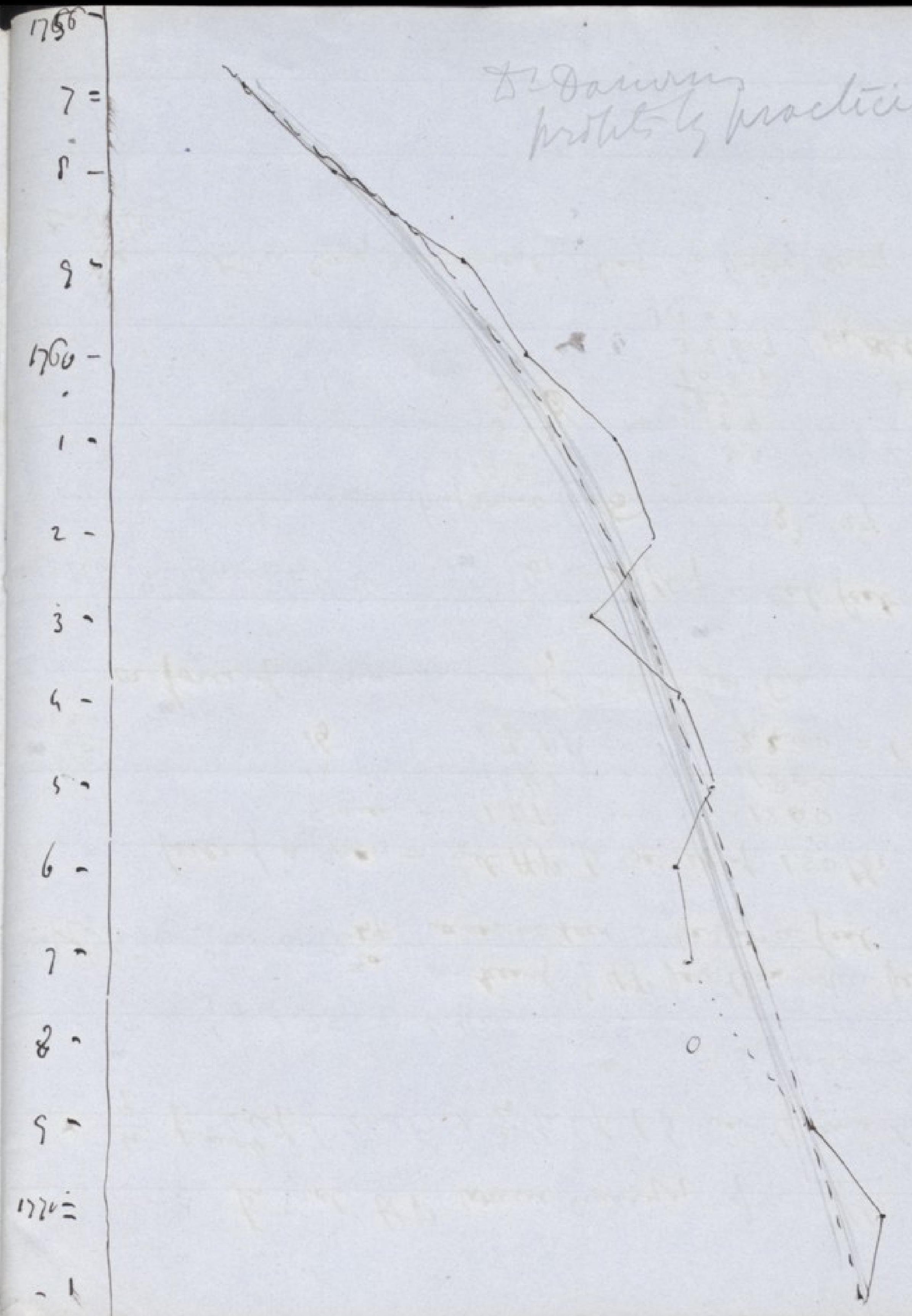
64/2240 (35
192
320
320

$3^3 = 27$ $4^3 = 64$



3.3
99
99
1089
3267
3267 ~~[illegible]~~

Mem utilise rising movement that the buoy may not be too bulky.



1756
7
8
9
1760
1
2
3
4
5
6
7
8
9
1770
1
Dr Darwin
probably practice

New University Club,
St. James's Street. S.W.

Dear Mr. Galton

I enclose the photograph which I promised. –

I will keep your secret strictly. I am glad to hear that you are going to patent it, as it sounds as if it ought to be a very great mercantile invention.

Will it possible to ungoke

f. 45v

your Ships; if not, they w^d^
be rather unmanageable in
rivers & harbours; will not
the danger of collisions be
much increased by the
great width & what will happen
when the helm has to be
turned hard to avoid any-
-thing? If one of the ships
got at all out of hand
it w^d^ be rather an awkward

f. 46

combination wont it.

My father is very incredulous in re the spirits.—

I am sorry to hear that Miss Fox is to have her familiars with her as 3 conjurors cd combine to do their tricks witht much chance of ~~being~~ found out

Yours very sincerely

George Darwin

23 Scarsdale Villas
Kensington W.
14 April 1872

My dear Sir

The actual forces operating on an Engine connecting two vessels in a troubled sea, such as you propose, are rather complicated, because you have to deal with fluid resistances, as well as with moving masses.

If you imagine two plates rigidly connected together, and embedded in a solid body, through which a sound wave passes in such a manner as to be in ~~different~~ opposite phases as it passes the plates, it is evident that the wave must either be stopped, or something must burst. And it might be possible, through an imperfect connection between the plates, to get out in the shape of work a very large portion of the whole energy of the wave.

With a fluid, we should take out very much less, for the plates or vessels would be free to move in the fluid. In fact, supposing neither of them to yaw, you might easily connect them by a rigid bridge, the resistance of which to elongation would stop your telescopic motion; and the resistance to bending would stop the angular reciprocation. I do not see my way to calculating these without making a great many assumptions; but it is worth while to point out that taking up work from these motions is equivalent to making stiff joints, and thereby goes to diminish the motions themselves.

If we assume a vessel to constitute an integral part of a uniform mean trochoidal wave – whose ~~mean~~ height is 7 feet, we may regard its whole energy of motion as equivalent to that of an equal mass of water, every particle of which moves through 22 feet in one wave-period. Calling this period 4 seconds, and the weight of the ship 100 tons, the height due to a velocity of 5½ feet per second is $\frac{(5 \cdot 5)^2}{64}$ ($\frac{22}{4} =$)

and the total energy is $\frac{(5 \cdot 5)^2}{64} \times 100$ foot tons. If we suppose this to be destroyed once ~~for~~ as each wave passes, and the whole work utilised, we get for the H.P.

$$\frac{(5 \cdot 5)^2}{64} \times \frac{224000}{4 \times 550} = \frac{55 \times 35}{40} = 48 \text{ H.P.}$$

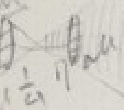
I think this represents all the work that we can practically have to deal with under the suppositions – namely that if the mean wave acting upon the ship be 7 feet high and the period 4", the whole work ~~of~~ that we have to deal with gives 48 H.P. for each of two vessels.

The fact, that your using the power impedes the motion, at once cuts down the efficiency to $\frac{1}{2}$ at most.

Since the vessels may be in any phase from the same to opposite, the mean efficiency will by this ~~case~~ cause be reducible by $\frac{1}{2}$

If the gear be on the broadside, so as necessarily to keep the vessels abreast or nearly so, there will be a further mean loss of $\frac{1}{2}$ due to the motion not being in the right direction.

? Even if one vessel were directly under the lee of the other, she would be in calm water, & the wind be at all under the lee except in about $\frac{1}{24}$ of all possible positions



These considerations ~~bring~~ bring down the H.P. to $\frac{1}{2} \times \frac{1}{2} \times \frac{1}{2} \times 48 = 6$ H.P. and this as I think expresses the mean H.P. which you would put into your gear from a simple series of waves such I have supposed.

In the next place; what you have obtained is 6 H.P. put into a series of drivers all working at various and varying speeds. You cannot make these drivers help one another except by some work-absorbent, like water to be raised, or air to be compressed. I do not think I am overstating the case in estimating that, what between this, and the friction of the Connector, and its various gear, 3/4^ths more would be lost. This would reduce the available H.P. to $1\frac{1}{2}$ H.P for each ship.

? $\frac{1}{2}$

I think I have ~~suggested~~ supposed as rough a sea as ships of 100 tons ~~could~~ displacement could venture to use such machinery in. A mean wave of 7 feet would represent a surface wave of 8. Would $1\frac{1}{2}$ or even 2 H.P. be of any use for 100 tons? A full powered vessel takes 1 I.H.P. per ton (displacement.).

Under any more favorable, a priori, plan the force w^d be 6 H.P.

It is pretty certain that under no circumstances could you reach 8 H.P per 100 tons if my ideas be correct.

There may be some points connected with ~~keel resistance~~ keel-resistance, et similia, which may affect these results. I can form no judgment on these; but I think

f. 51 5

they are quite as likely to be against useful work, as in favour of it.

Then comes a further question. You have possibly 48 H.P. at work on your gear and certainly only 8 H.P. to come out of it – possibly only 1 or 2 H.P. Moreover your prime mover is an actual mass in motion. Is not this discrepancy itself a source both of inefficiency and danger? You have to provide strength and weight for 48, and you have only 6 to meet the friction.

My theoretical conclusion is therefore against the machine being of practical utility, by reason of its probable efficiency not being adequate to its cost and to its inconvenience.

I consider, however, that both the idea and the machinery are ingenious, in a very high degree; and I should be sorry if you allowed one adverse opinion (coming from myself) to discourage you from trial. If you were to show your machine to any body else, my letter will might be of some use as a basis of

f. 52 6

calculation. Could you not show both to Mr. Bramwell?

If you wish to put it in practice, I think the best scale to do it would be in boats of 15 to 20 feet long, length about three times the beam. If you were to use smaller boats, they would hardly be safe for you or your gear. The kind of boat I mean is the open boat commonly used in the channel and the West of England for fishing under sail. A ship's long boat or jolly boat might do.

If you wish to discuss this letter with me, please let me have it again, as I can't find time to make a copy.

Very truly yours

C. W. Merrifield

Fras. Galton Esq

f. 53r

15 April 1872

My dear Sir

I think there is an error in one of my factors $\frac{1}{2}$. The last of them should be $\frac{2}{\pi}$ or $\frac{2}{3}$ nearly. This does not however much affect the argument.

You ask will the machine be of any use for measuring sea disturbance? I think not, in its present form. There are

f. 53v

two difficulties, one that it is rather complex and therefore weak, and therefore not fitted to register against a fixed beacon where it must remain whatever the weather. Again taking off work from it is equivalent to stiffening the joints and thereby reducing the motion and thus the work. You therefore don't know exactly what you are

f. 54r

measuring. I think it would not give reliable results

I think a modification of Admiral Paris's "trace-vagues" for which see vol VIII for 1867 of the Trans I.N.A. – adapted ~~to~~ a beacon mast instead of a floating would ~~also~~ answer better in a tideless sea, and that some corresponding arrangement could be devised for tidal waters. I should

f. 54v

prefer registering the motion
to registering work. I will try
and think it out and let
you know if I can tap an idea.

Ffly yours
C. W. Merrifield

F. Galton Esq

Berkswell Oct 6/71

My dear Galton

I send you a [illegible] & I fear a [illegible] answer to your question, [illegible] to save time & perhaps I am not so clear therefore as I should be. I meant [illegible] –

f. 55v

Suppose the air pumped in by your apparatus to be admitted in the first instance, to a portion of the boiler separated from the steam by a movable diaphragm ~~there a cert~~ then the pumping work would be done upon the steam in the compressible enclosure. ~~Supposing the steam to be a~~ By the property of vapours as discovered by many of the workers at energy - the steam

f. 56r

being compressed would become Superheated that is to say its density would be increased by the compression but its temperature would be increased yet more rapidly than the law ~~S_f~~ density $= f(t)$ ~~demands~~ — I therefore think it is a good thing to say that its density & specific volume will vary according to the law $pv^{\mu} = C$

The effect therefore of the operation in this form would be to increase the pressure & temperature of the steam

in ~~the~~ its compartment of the
boiler & therefore to increase the
disposable work for the purpose of
the machine - & this increase
will be the ~~same~~ equal to the work done
upon the movable diaphragm by
the pumped in air -

I ~~am not~~ cannot see that
the mixing of the air with
the steam will affect this
result -

I am patient to hear some news
of the quantum

yours ever
J W Water

f. 57r

The Rectory,
Berkeswell,
Coventry.

Oct = 13/7[illegible]

My dear Galton

Don't think that I have forgotten you. The problem you now suggest is very difficult for accurate solution — If it were a case of one gas being permanently pumped into another at the higher temperature there will not be much difficulty because the ratio of their specific heats is constant – but in the case of a vapour the action is much more complex – the vapour being originally at saturation is compressed by the pressure of the ~~is [illegible] of ether~~ ~~has work done~~ of injected air – this compression (of itself) will bring the vapour to the state of superheated vapour, then owing to the presence of the air being a lower temperature, this of course reduces the temperature of the

f. 58r

superheated vapour and I think it will be a very difficult thing for anybody to undertake the calculation & see whether this reduction of temperature is more or less compensated by the elevation arising from the compression — In Meanwhile, as an ad interim suggestion could you not manage that your injected air was made to pass through a furnace, or heated chamber before reaching the boiler.

f. 58v

then of course one of the difficulties at least of the calculation that I have referred to would disappear.

– The additional heat taken from the furnace becomes a matter of the simplest possible calculation (knowing the specific heat of the air).

If this suggestion should be of any value I would endeavour to find out to what extent the additional energy of the mixture in the boiler more than compensates for the additional consumption of heat to which I have referred

F. Galton Esq

Yours very truly

H W Watson

Berkswell Rectory
Coventry Jan^y 5/72

My dear Galton

If I did not know that you had condescended to read my little book ill as we were I would not now trouble you. The publishers are calling for a 2^d. edition and I have been writing to such of my friends as like yourself will be at all

f. 59v

chief to help me asking them to favour me with such suggestions for its improvement as may occur to them – I am hampered in my alterations by the fact that the thing is stereotyped & therefore the paging at any rate must remain – You never answered a question I put to you several weeks ago à propos of your new

f. 60

source of nervous energy — I trust the idea has not been thrown aside by you. I trust also that Mrs Galton & yourself are quite well — I am expecting to see Hawkins in a day or two —

With kindest regards
Believe me
very truly yours
H W Watson

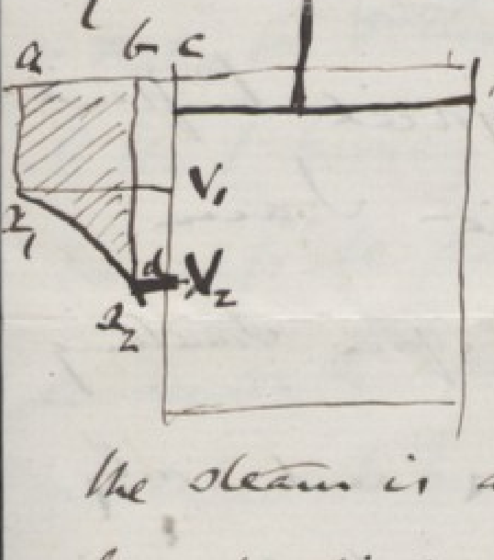
F Galton Esq
FRS

Berkswell Rectory
Coventry Jan^y 13/72

My dear Galton

I am truly rejoiced to find that you are so sanguine — I am confident you have hit upon something real & not a chimera and only hope that you may be able to bring it to some practical end — I am not inclined to think that you could utilise the power you have discovered in the way you suggested of pumping

P.S. Since the [illegible] for an effective air engine are that the air should enter [illegible] before or [illegible] you might perhaps use your power in this way [illegible] for steam engines) but that you can [illegible] — If anything [illegible] & you [illegible] to ask so far the [illegible] is in my [illegible] & [illegible] in my [illegible] air into the boiler and to shew you my reasons I will analyse the action of a double action engine if you will have the patience to consider my statement — The state of things is just this —



A mass M of Vapour & Water, in the form of drops mixed with the steam is admitted from the boiler above the piston at a certain temperature and corresponding pressure represented in the figure by the ordinate ac — The communication with the boiler being left open until the piston has moved to the point V1 Then the steam is shut off and the piston is pushed by the expansion of the

f. 62r

till it reaches V_2 or d, part of the steam being thereby condensed - the communication below the piston with the condenser is kept open - the pressure in the condenser being ~~kept~~ of course much smaller than ac, as represented by bc - (say) as in the best engines the expansion continues till the pressure above the piston at V_2 is equal to bc, so that bx_2 is ll^l to cd - Then the part above the piston is opened to the condenser & that below to the boiler and the piston is pushed up the vapour above being at the constant pressure bc - The mass M which is in the condenser is pumped back to the boiler by the pump worked by the engine & is there raised to its original

f. 62v

temperature & pressure ac & thus the cycle is completed – A moments inspection will shew you that in this cycle the mass M has yielded an amount of work represented by the area of the shaded figure ax_1x_2b & this is easily calculated So that knowing the heat required to raise the mass M from the temperature of the condenser to steam at pressure ac we can calculate how much of this heat is converted into useful work & therefore the heat required per second for a given horsepower – Now suppose we pumped air into the boiler at the pressure ac by using hitherto wasted energy what should we strike? The only difference that I can see would be that for a stroke & return we should require a smaller mass than M of vapour & water – say M_1, the ~~[illegible]~~ remainder M_2 being composed of air. * M_2 would have to be heated to the temperature of the steam & then the mixture of air & vapour would expand together ~~At full pressure this will~~ ~~Now after the [illegible] boiler [illegible] should~~ ~~above the piston~~

Now when the communication with the condenser is opened above the piston for the piston to ascend the air above is forced into the condenser along with the steam & water but whereas the elastic force of the latter is at once reduced to a very small constant quantity by cold f 63v

that of the air is not so –
It seems to me that this method might perhaps be tried successfully in a high pressure, non condensing engine, but then this would not answer I suppose at sea where the condensed vapour is required by reason of the limited water supply. Of course the vapour & air would not expand according to the same curve $x_1 x_2$, that of the air being an equitalural I take it but this does not much matter as the pres. at any time will be the sum of the press. & could be calculated. The saving would be in the difference of heat required to ~~...~~ heat & evaporate the mass M to pres. α & that to heat M_1 to that press. & the air M_2 to the corresponding temp –

Ever yours Cy
H. W. Watson

The Rectory,
Berkeswell,
Coventry.

Feb: 24/72

My dear Galton

Whereabouts is the new source of energy just now? I have been waiting with much curious expectation for a long time past hoping to hear something.

I have had some conversation with George Bidder (the elder & celebrated one) on the possibility of

f. 64v

utilising any newly formed energy (supposing such a thing possible) in the way you mention, viz by pumping into the boiler. He says they will make it do work directly, i.e. work an independent engine — and although he did not quite take the same view that I do about the impossibility of getting the vacuum in the return

F. 65r

sufficiently quickly. — yet on reconsideration I recur entirely to my own opinion — could explain it thoroughly viva voce. — Of course I never hinted at your source of energy, and he was much amused at my ~~s~~ believing that such a thing really did or could exist —

I suppose you have heard of Charles Evans & his promotion. My govt

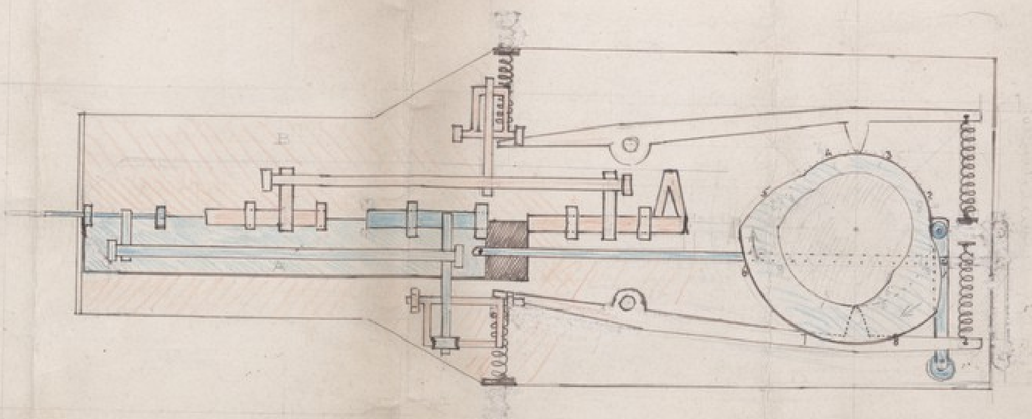
f. 65v

Iquria has given him a fatter & better living than mine, to wit – Solihull which as coming from these parts you will know – He is of course nominally presented by the former patron, the late incumbent having died & no one at present suspects the source of his promotion –

Ever yours sincerely
H. W. Watson

F. Galton Esq.
R. S.

1 a descend
2 a gripped
3 b loosed
4 still
5 a ascend
6 b gripped
7 a loosed
8 still
1
2
3 repeat will
4
5
6
7
8 ... and print.



T V

The "Tactor". machine

f. 1r

The instruments that the Sub. Com^e of the R.G.S had especially in view are.

1st (and principally) the Sextant.

What dependance can be placed on a single reading, at 2 or 3 different points of its scale? (exclusive of any error that may be due to the shades) the sextant being ~~[illegible]~~ put into true adjustment.?

Do the mirrors & shades shew any appreciable inaccuracy under the telescope that is attached to the Sextant.?

Does the index arm follow the the motion of the tangent screw with perfect freedom?

Are these any obvious faults of

f. 1v

workmanship or design which might render the instrument unduly liable to get out of order & difficult to readjust. ?

2. Roof of mercurial horizon. Have its glasses any appreciable error ~~which~~ under the power of the sextant telescope. ?

3. Prismatic Compass. What is its index error & what ~~its error~~ dependance can be placed on its readings at ~~different~~ other points of its scale. ?

4. Smaller Telescopes intended for the observation

f. 2

of Jupiter satellites and occultation of stars down to the 5th degree of magnitude inclusive. — Are they good enough for the work.?

tin

Extract from Report of Kew Committee to Council of the British Association 17 Nov. 1859. H. R. H. the Prince Consort, President in the Chair.

The General Committee assembled in Leeds, passed the following resolution in September 1858, viz. :—

"That the consideration of the Kew Committee be requested to the best means of removing the difficulty which is now experienced by officers proceeding on Government Expeditions, and by other scientific travellers in procuring instruments for determination of geographical position, of the most approved portable construction, and properly verified. That the interest of geographical science would be materially advanced by similar measures being taken by the Kew Committee in respect to such instruments, to those which have proved so beneficial in the case of magnetical and meteorological instruments."

This resolution having been communicated by the Assistant General Secretary to the Kew Committee, two preliminary measures appeared to them desirable to enable them to carry the wishes of the General Committee into practical effect. The one was to ask Mr. Francis Galton, the Honorary Secretary of the Royal Geographical Society, at whose suggestion the resolution was understood to have been brought forward, to become a Member of the Kew Committee. The second was to obtain by purchase (when funds should be found for the purpose), from the instrument-makers of highest repute in Munich, Berlin, and Paris, carefully selected instruments amongst those most esteemed on the Continent for the geographical purposes referred to, with a view of subjecting them to comparison with each other, and with British instruments, both in respect to general adaptation and to the mechanism of special parts.

It will be in the recollection of the Council, that the further proceedings of the Kew Committee in this matter were suspended, partly by the severe illness of Mr. Francis Galton, which deprived them of the assistance they had hoped to receive from that gentleman, and partly by their having no available funds to purchase foreign instruments for an examination of their relative merits with those of England.

The difficulty in regard to Mr. Galton has been happily removed by his perfect recovery; but the want of funds available for the prosecution of inquiries which should guide the Kew Committee in rendering the same service to geographical instruments that they are considered to have accomplished in respect to magnetical and meteorological instruments, still remains. The readiness of the Kew Committee to proceed in the matter, if this difficulty were removed, was duly stated in reply to questions which were asked at the recent Meeting of the General Committee at Aberdeen, when it was suggested by one of the Members of the General Committee, that perhaps the necessary funds might be supplied by the Royal Geographical Society, who were stated to have concurred in the proposition made by the Geographical Section of the Association at Leeds, and who must undoubtedly be supposed to have a special interest in the improvement of instruments for Geographical Determinations.

JOHN GASSIOT, *Chairman.*

Extracted by
— John Phillips —

Examination
of Sextants
1860

Prize of £50 or a Gold Medal to the Designer or Maker of the most serviceable Reflecting Instrument for the Measurement of Angles.

The Council of the Royal Geographical Society having taken into consideration the importance of Reflecting Instruments to practical geographers, and acting under the belief that many improvements in sextants and circles have been devised, both in this country and abroad, which are not generally known and have never been adequately combined in a single design, have determined to offer a prize of 50*l.* to the designer or maker of that Reflecting Instrument which shall in their opinion most nearly fulfil the following conditions, in addition to that of general accuracy :—

1. Portability; simplicity of packing; security from concussion.
2. Capability of measuring large angles.
3. Independence of natural or detached horizon.
4. Distinctness in reading off, by day and by night.
5. Convenience in handling; adaptability to stand for use in field.
6. Efficiency of adjustments.
7. Power of measuring faint objects.

The divided arc to be from 3 to 8 inches radius.

The instruments to be sent in cases, suited for immediate use in land travel.

The instruments will be received at the Society's rooms until the close of the present year.

f. 5r

The Haven Ealing

February 20th /60

My dear Galton

I think the examination of reflecting instruments and theodolites may be safely divided into three sections

1st With respect to the ~~power~~ excellence of their telescopes

2nd 3d With reference to the arc & graduation centering its Verniers

3d 4th General adjustment

f. 5v

Under the 2nd article precision in ~~division~~ measurement & clearness of ~~character~~ division would constitute the examination of the main arc while perspicacity firmness in clamping, & absence of parallax would be the test for the Verneer.

Under the 3rd head simplicity of adjustment & stability when adjusted whether exposed to a change of temperature or a certain amount of rough carriage would enable the examiner to give the instrument a certain distinct

f. 6r

Character under the head

In the event of an instrument taking a decidedly good character in all three sections a first class certificate ~~should~~ might be issued

Should it fail in one a second

——— in two a third

The second and the third class certificates should specify the particular section for which the certificate has been given.

I see the Admiralty have just offered a reward for the best nautical telescope

f. 6v

I have been laid up this last week by my old enemy fever & ague - & my head is far from being as clear as it ought to be but I hope to be able to get to the Council on Monday next

Believe me to be
yours very truly

R. Collinson

f. 75

13. Ashley Place
Feb. 26th 1860.

My dear Sir

In reflecting since on what you told me regarding the intentions of the Geog: Society, it appears to me that the sum proposed as the reward of improved reflecting Instt. for determining geographical positions is scarcely sufficient to induce such a competition

Francis Galton Esq.

f. 7v

as might be obtained; if the prize were £100, for example, instead of £50. It was my intention to have attended the Council tomorrow for the purpose of speaking to you on the subject; and of supporting such a proposition if made by you. But I have unfortunately taken cold, and having many pressing duties next week. I must

f. 8r

do my best to get rid of the cold.

Should the sum be increased to £100, it might be desirable to notify it to the principal instrument makers in Paris, Berlin, Munich &c; some of them, I have no doubt, would send instruments; more particularly as the duty on foreign instruments will now I believe be taken off.

f. 8v

I should be very glad to assist in any way in making known the matter.

When you have made your approval, arranged the price, &c, you will probably determine the kind of examination you would wish them to undergo at Kew; which would enable the Committee to tell you at once the fee for examination & certificate, which (judging from the charge on Meteorological Instruments) would be very small.

Sincerely yours
Edward Sabine

f. 9r

13. Ashley Place.
Feb. 16.

My dear Sir;

I think that both your resolutions are good in themselves, and are likely to lead to beneficial results. The Kew Committee will I doubt not be happy to give any aid in their power. They will wish to know what are the particular instruments which you will desire to be examined; to what points the examination

Francis Galton Esq.

f. 9v

should be rejected; and what is to be the degree of performance implied by the certificate. I suppose these points will be required to be known, before the amount of the probable cost of examination can be judged of. I have forwarded your letter to the Chairman, and I presume he will summon

f. 10

the Comd. as soon as he receives
the Secretaries letter.

Sincerely yours
Edward Sabine.

f. 11r

13. Ashley Place.
Nov. 28th. 59

My dear Sir

My reply to your note of this day must be as one of the members of the Kew Committee. We were asked, (not at our own solicitation) to undertake the task of improving the British instruments for geographical determinations. Our reply was that we were quite willing to do so, if funds were placed at our disposal for the purpose. The view of the Committee, so far as they had discussed the subject, was, I believe, to have asked in such case one or two of their members to visit Paris, Berlin, and Munich, (of course at their own expense), there to select for purchase out of the funds such

Francis Galton Esq.

f. 11v

instruments as, upon inspection and Consideration, they should think most likely to be useful for study and examination in comparison with those of this Country; and thus to lead to the suggestion & adoption of improvements in the latter.

While the Kew Committee, however, were quite willing to have undertaken this as a public duty, they have plenty on their hands otherwise; and I doubt not would be well pleased to see it executed by the Geographical Society without their intervention. But I do not believe they would think the course now suggested admissible. If they

f. 12r

understook the matter. The selection &
purchase of instruments would have to
be left to their unfettered discretion:
and I, as one of their members, could
not take part in a Committee which
should have to prepare beforehand
a detailed plan of expenditure to be
submitted to the Council of the Geogra-
-phical Society: or in any respect to
limit the free discretion of the Kew
Committee in the mode of proceeding
in the inquiry should it be undertaken
by them. Add to this that I should not
be a good member of such a Comm^{ee}:
on your purpose, for settling beforehand
what instruments should be purchased,

f. 12v

not having a sufficient knowledge of those now made on the Continent: in order to form a judgment I should find a previous personal inspection absolutely indispensable.

Sincerely yours

Edward Sabine.

Sir, I send you an Hypsometrical Instrument of my contrivance – It is the result of several experiments

In the first instance, with a view ~~of~~ towards Economy of Spirits of wine, of weight & of bulk I endeavoured to ascertain the smallest quantity of boiling water that could give accurate results

Secondly I desired to contrive a heating apparatus ~~make a lanthorn~~ that should be available on the hill side without ~~a~~ shelter, & that should burn, on an emergency, other fuel than Spirits of wine.

I found that if a thermometer were plunged into a small vessel of water, boiling above ~~over~~ a lamp, that there was a great irregularity of heat & that the mercury oscillated in the stem ~~beyond the scale~~ to an extent that could not be tolerated.

I then tried the system of supporting ~~[illegible]~~ a second vessel, with perforated sides, within the outer one & ~~[illegible]~~ enclosing the thermometer bulb ~~should be enclosed~~ within the second vessel. This acted fairly, but nothing acted better than simply tying a piece of muslin loosely round the bulb. An instrument graduated boldly to $\frac{1}{20}$th of a degrees, shews no oscillation, when thus protected, when plunged into ~~a~~ one ounce vessel full of water boiling above ~~[illegible]~~ a common candle. I have therefore adopted the muslin bag in the present arrangements.

As regards the heating apparatus I shut up ~~enclose~~ the boiler in a small lanthorn, with perforated plates at bottom & at top. When the cover is taken off, the boiling water is exposed. The thermometer does not pass through the cover, but through a cork fitted into a nozzle at the side of the boiler. It is ~~thus~~ more manageable in many respects ~~in this position~~ than in the one commonly adopted & it is necessary at a constant distance from the bottom of the boiler. Only about $2\frac{1}{2}$ inches of its entire length is unavailable for graduation; Hence a short stout thermometer of 6 inches in entire length

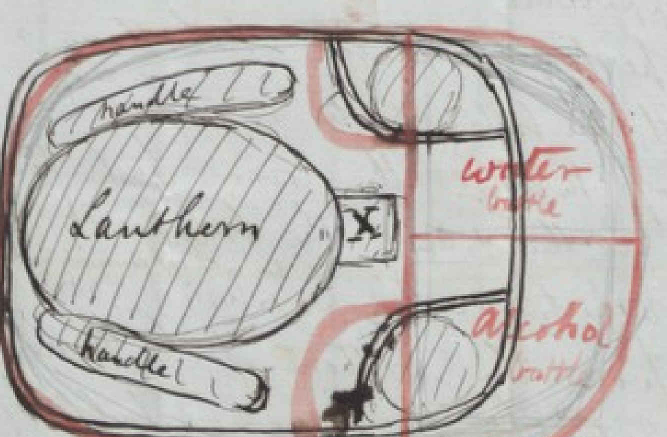
length will have about 3.6 inches on which to engrave a scale of 36 degrees (from 180° to 216°) — or $\frac{1}{10}$ inch to a degree. — & a tenth part of this, or $\frac{1}{100}$ inch, stands roughly speaking, for 50 feet of altitude. —

I find the entire operation of unpacking the case, taking an hypsometrical operation on the hill side & repacking it requires minutes. I light the lamp with a lucifer match, not through the door, but down from the top — the cover & the upper compartment having been removed.

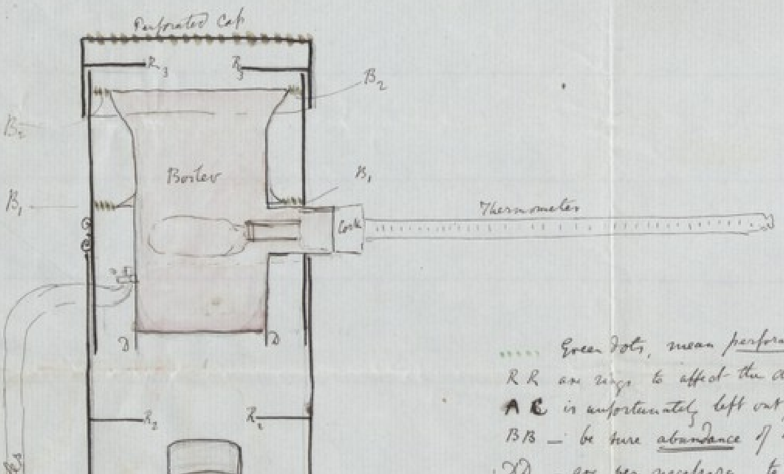
The case should contain (1) Lanthern & spirit lamp (2) Thermometers (3) Lucifers 4 A good sized bottle (4 oz) of spare spirit, (5) a wide mouthed copper bottle of water (3 oz) into which the remains of each boiling experiment may be returned.

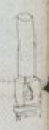
The thermometers pack thus..

The case I send is unnecessarily large — but it is a common mistake to err in the opposite direction — Neither do I think it practically advisable that the bottles should pack up within the lanthern. They would rattle about & if the inside of the lanthern were blackened by oil, would be very dirty indeed. Besides all this they would be too small for regular use.



The black lines shew the Ground plan of the case I send; the red lines those of the case I should propose. Both bottles would be copper with screw stoppers; — Alcohol small mouth, Water large mouth. — Lucifers would easily pack above X





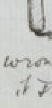
..... Green dots, mean perforation

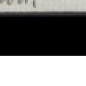
R R are rings to affect the draught of air R_2R_2 acts like the ring in an Argand lamp glass

A C is unfortunately left out in the model sent. – It is ~~[illegible]~~ ^simple a^ plate.

B B – be sure abundance of air space is left here, for the upward draught.

D D – are very necessary to divert any drops of water that may be thrown out of the boiler (by rapid boiling or otherwise) from dropping on ^to^ the flame ^(putting it out)^. If it were not for D D, they would ~~run the~~ [sketch] follow the outside of the boiler & drop from the middle of its base.

Handles – become a little hot. – I do not bind them round with string because that soon becomes dirty – Arrange them ^any^ on the principle ^used for^ of the handles of a tea pots, they  a wooden tube round iron handle.

Door. – is on the wrong side of the model sent. the ink lines on the model shew where it should be. viz: thus 

(The instrument is not lighted through the door, in blowy weather, but down through the top, the boiler part having been removed.)

I send you an hypsometrical apparatus of my contrivance ~~which has been~~ This is the result of ~~many~~ several experiments. ~~I was desirous to make it as small~~ I wished first to contrive first in instance ~~strong as possible~~ secure, ~~that is to say~~ that a minimum of boiling water should be employed as that would require & a minimum of spirits of wine or other fuel be ~~necessary~~ used to heat it. 2nd that the thermometer should be ~~so~~ immersed in such a manner only that a trifling portion of its length would ~~alone~~ be unavoidable ~~to read from~~ for ~~division~~ graduations & 3rdly that ~~the~~ apparatus ~~could~~ should admit of being used ~~anywhere in the open air~~ unsheltered, on the hill side, without practical difficulty.

~~In the~~ If a thermometer be simply plunged into a small vessel of boiling water over a ~~lamp~~ lamp the mercury in the scale will be ~~the~~ far too ~~long~~ unsteady to give any useful results. I tried several plans of double vessels, the inner one being perforated in order to enclose a volume of heated water ~~at boiling heat~~ undisturbed by the irregular ebullition of the water that surrounded it. After many trials I found nothing ~~more~~ efficacious as certainly none was simpler than that device of tying a bit of muslin loosely round the bulb of the thermometer. An instrument graduated boldly to $\frac{1}{20}$th of a degree ~~remains~~ shews no oscillation when ~~boiling~~ placed in a single fluid ounce of water that has been set to boil ~~over a lamp~~ over a flickering lamp. I have adopted this method by muslin bag ~~to~~ the present arrangement. — ~~With a view~~

~~faking~~ 2nd the thermometer passes ~~into~~ through the side of the boiler. There is a nozzle made in the boiler to receive a cork through which the thermometer passes. It is then at a constant distance above the ~~the~~ bottom of the boiler & ~~the moreover the~~ only about $2\frac{1}{3}$ inches of the entire length of the therm: is unavailable for graduation. Thus if the thermometer be about 6 inches in entire length, $3\frac{2}{3}$ inches will be available for graduation from deg 180° to 216 or [illegible] degree.

Lastly. I enclose the boiler in a small lanthern fed with air from below through perforated plates & having a perforated cap above. Spirits of wine is far the cleanest & best fuel ~~but~~ but oil or candles or even sticks can be used. The entire ~~experiment~~ hypsometrical ~~observation~~ of including unpacking the case & repacking it requires less than 10 minutes. The case includes lanthern Therm: Lucifers than Spirits W. water.

Design for
Boiling
Thermometer

? date & for whom

f. 41r

I send you a hypsometrical apparatus which I have constructed after several experiments to meet the following wants.

1st power of using a short strong thermometer, such as can be carried without risk

2nd do minimum of water & duration of heat, so that the heat of a candle or oil lamp shall suffice in a very small quantity of spirits of wine is required to raise it to the boiling

3rd a small lantern in which the boiling apparatus shall be contained & secured from the effect of wind & weather.

In order to meet No 2. I tried ~~many plans of double vessels~~ of various designs of a perforated vessel placed inside the boiler. ~~the layer of water between them acting as a~~ ~~aiding uniformity~~ but nothing ~~acted so well~~ or proved so successful or was so simple as the tying a loose bit of muslin round the bulb of the thermometer. It fully sufficed to enclose a small quantity of water at a boiling heat. When in use the mercury of the thermometer becomes perfectly steady. I find an ounce of water or a ⅓ of spirits of wine is more than enough to use in a hypsometrical observation. I employ a little copper boiler with an opening in its side ~~in which~~ which having a cork with a small hole is able to thrust in a thermometer passing through a hole in its centre. The thermometer is inches long & graduated from 180 to 212 allowing for 1° & divided to half degrees. which the eye subdivides to fourths or 1/10 of a degree.

As to the lanthorn, it admits the air through perforated plates from below & lets it out above on the same principle. ~~there is an arrangement by which it~~ To light it having put the side tube of the boiler passes through its side. ~~water & thermometer in the boiler~~ & having unscrewed the lamp to light ~~a match~~ & introduce it not through the door but down (It is best lighted, in blowing weather) from above, before putting in the boiler.

2.3
3.2
5.5

500 ft

2½ inches are lost

3½ [illegible] 32°

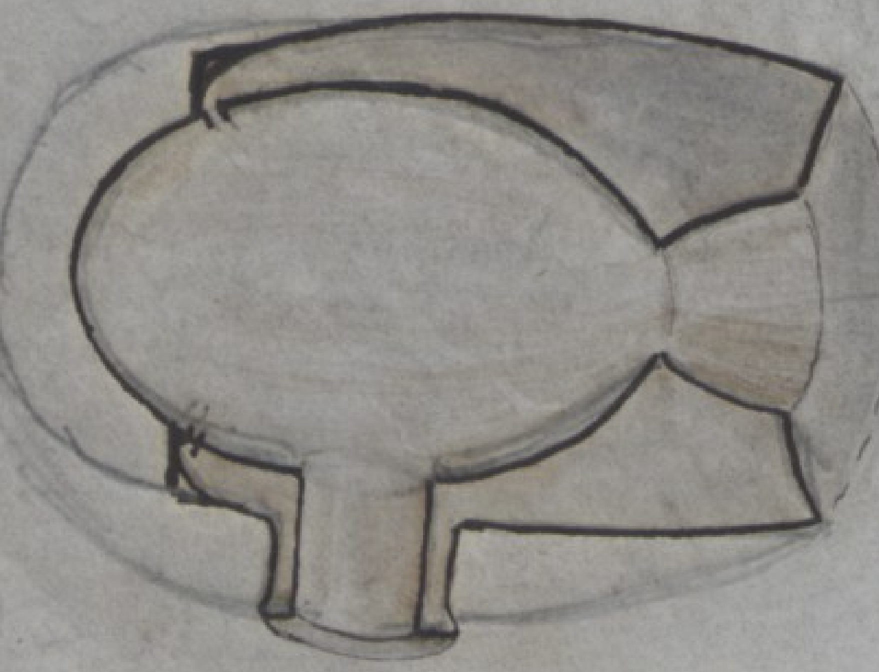
2.3 1.3

.3 1.4
1

$\frac{1}{5}$ inch to 100 ft

$\frac{1}{20}$ in 250 ft

Boiling point [illegible]

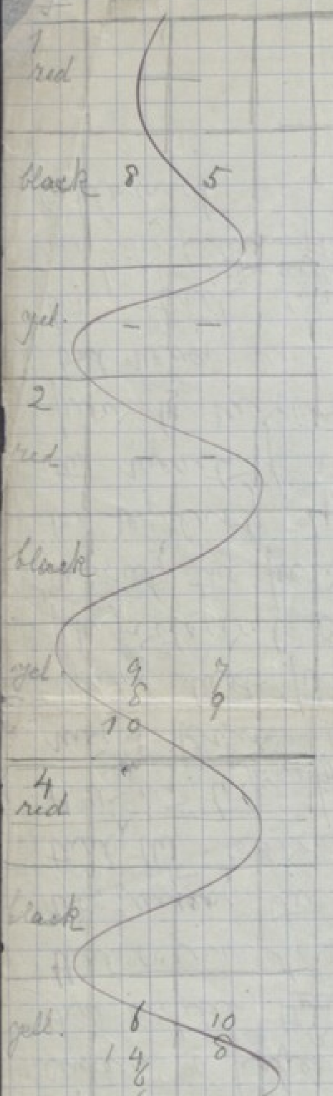


f. 5

f. 1r

Lighthouses

Recently when at Ramsgate I found myself much at a loss in interpreting at night the slow distinguishing signals of the light-ships anchored by the Goodwin Sands. And now having by me the just published Journal of the British Association which contains a paper on Light-House signals by Sir James Douglas, that implies that they are still under consideration I send the idea that occurred to me at Ramsgate. It is that while fully recognising the ~~merits~~ advantage of long and short flashes in signals, it seems to me that owing to the tediousness of each ~~light house~~ signal ~~makes~~ it is advisable that its total period should be ~~said~~ so arranged ~~well defined~~ so that the observer might be prepared for the cessation ~~know when it ceased should cease.~~ with this speed I would make the period of successive signals conform to the ~~indications~~ beats of that useful physiological chronometer which photographers largely depend upon, namely the period of a complete breath, which is very nearly a very regularly 4 seconds. In short I would propose that the merits of a system of signals should be tried whose total periods might in the various cases be 4, or 8, or 12 seconds (as most convenient in each particular instance), but never any other number. The ratio of the short to the long flash ~~would~~ remaining as at present, viz. as 1 to 3, perhaps this absolute lengths would be no longer ~~...~~ generally, governed by the condition just explained.



1
red
black 8 5
gel
2
red
black
gel 9 7
8 9
10
4
red
black
gell 6 10
14 8
6
16
18
16
11
17
5
red 14 10
12
12
black 12 5

Humidity clock

1f

Humidity Clock

1st Period
aged

Charles Newman

2nd Period
aged

f 1r

Clock for No of hours during which humidity has exceeded a certain datum value

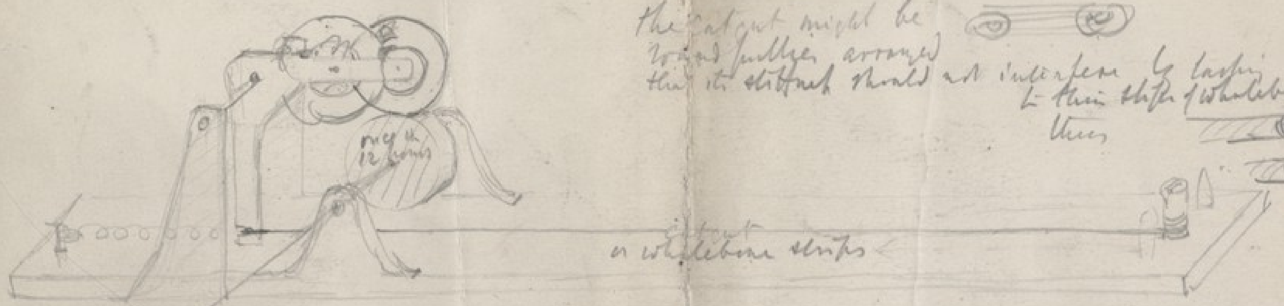
See inside

3rd Period
aged

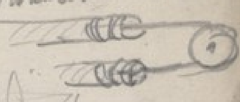
4th Period
aged

to shew no. of hours per day during which humidity has exceeded a datum value,

a row of 2 or 3 of them

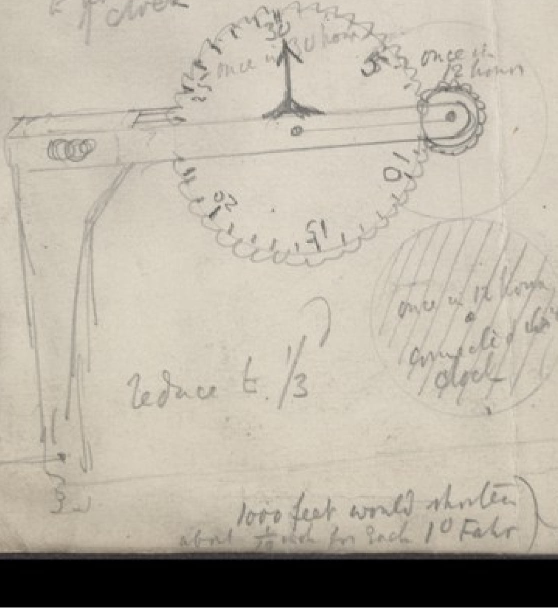


the catgut might be round pulleys arranged that its stiffness should not interfere by lashing to thin strips of whalebone or steel strings



attached to [illegible] movement of clock

when catgut is ~~taught~~ shortened the roller is lifted & there is no ~~[illegible]~~ ~~rotated~~ rotating motion impressed on it; otherwise there is.



reduce to 1/3

or it might squeeze out a sort of aneroid box arrangement. 1st the one that acts on the lever & subsequently another big one ~~[illegible]~~ a stronger spring ~~repeated~~

[illegible] 10 / d 2

Same arrangement to be used for temperature but giving as to the best thermometer either a long piano forte steel wire (or wires) stretched along ground in gallery or a 2 gallons [illegible] salt water and thermometer bulb in float

1000 feet would shorten about [illegible] for each 1° Fahr

it would increase about 30 [illegible] for each 1° Fahr = [illegible]