Observations of the Height, Direction and Rate of Motion of Clouds

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METEOROLOGICAL COUNCIL.

METHOD of DETERMINING the DISTANCE and HEIGHT of CLOUDS and the DIRECTION and RATE of their MOTION parallel to the EARTH'S SURFACE.

There are three observers and three instruments on stands. One of these is a "Finder" (Fig. 1) having a pair of parallel sights, and mounted like a rude theodolite. The other two are angular instruments of the same pattern (Fig. 2), consisting of a tube laid horizontally in Y-shaped supports, and having a graduated circle with its attached arm and sights fixed flat against one of the projecting ends of the tube.

At the beginning of the measurement all three observers stand at the middle station where the Finder is mounted. Two of them look simultaneously through it, and direct it to various spots or interspaces in the cloud, conferring the while together until they have selected one that seems suitable. They then hurriedly separate, and hasten, the one to the right and the other to the left, to their respective stations, where their angular instruments have been so laid that the axes of their tubes lie in the same straight line. Each observer quickly rotates the tube of his instrument and turns the arm with the sights until he aligns them with the cloud-spot. He then continues to follow its motion, awaiting a signal to stop, which is given by a whistle from the third observer, who remains at the middle station. Thus the observations are made simultaneously at the two ends of a long base of the same cloud-spot, and the angles that are read off from the divided circles are the basal angles of a triangle whose base is the line separating the two stations, and whose apex is the cloud-spot. The distance of the latter from either of the stations can consequently be determined.

The third observer, immediately after his companions have left him to hurry to their respective stations, goes to the "Finder," which remains in position, and he re-adjusts it, if not to identically the same spot that had been selected, at all events to one closely adjacent, and he notes the time. He then reads off the altitude and azimuth of the spot. Again, after he has given the signal whistle he repeats the process. Thus he obtains the altitude and azimuth of the same cloud-spot at the beginning and at the end of a known interval of time, the latter of which is practically identical with the moment at which the observations to determine the distance of the cloud were made.

Thus all the necessary data are procured on the supposition either that the clouds are moving parallel to the earth's surface or that we are only concerned with that component of their actual motion which lies in a plane parallel to the earth's surface. We may also assume, without sensible error, that the distance of the cloud-spot and its altitude from the middle station is the same as from either of the outer stations. The calculations are therefore very simple. From the distance of the cloud-spot from either outer station & ~~or~~ from its altitude observed at the middle station we obtain its height. From the double observation of altitude and azimuth from the middle station we calculate the direction of its drift in the interval, and from the same observation, combined with the knowledge of its distance and of the elapsed time, we calculate the rate of its motion.

The probable minimum efficiency of the method may be calculated on the following data:—

(1.) Clouds frequently change their shapes so rapidly that a selected spot may cease to be recognisable after the lapse of half a minute.

(2.) The definition of cloud-spots is so imperfect that the liability of error in determining the parallax of the base line may be taken as high as a quarter of a degree.

(3.) The observers may not be reckoned upon as able to run for 25 seconds at a greater rate than 5½ miles per hour, without losing steadiness of hand.

(4.) After arriving at their respective stations, not less than five seconds should be allowed to the observers to direct the sights of their instruments upon the cloud-spot.

(5.) In order that the determination of distance may be of use, its error should not exceed one-tenth of the true value.

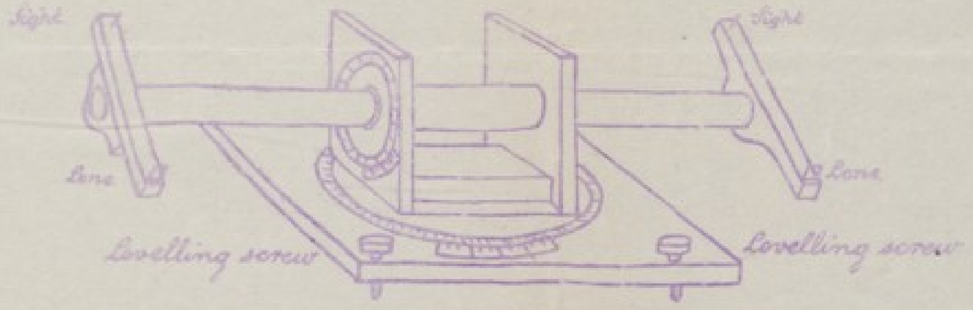
Putting these data together, it will be found that each observer will have time to run 200 feet or thereabouts from the middle station; consequently the length of the base line will be 400 feet. Also that the parallax of the base line must not be less than tenfold the quarter of a degree, that is, not less than 2°·5, consequently the distance of the cloud must not exceed 10,000 feet.

It follows that even under somewhat over-rigorous suppositions, ordinary clouds ought to be measured very efficiently. When the durability of form is greater than has been supposed above, and notably in the case of cirrus, a minute or more might be allowed to each observer for getting to his station. It is also feasible in many cases to use a more rapid and easy means of locomotion than by foot. Tricycles, for example, might be used. It is therefore probable that if this method were developed to its fullest extent, an efficiency at least four times as great as has been estimated above could in most cases be obtained, and in all cases it could be nearly doubled.

Francis Galton
April/83

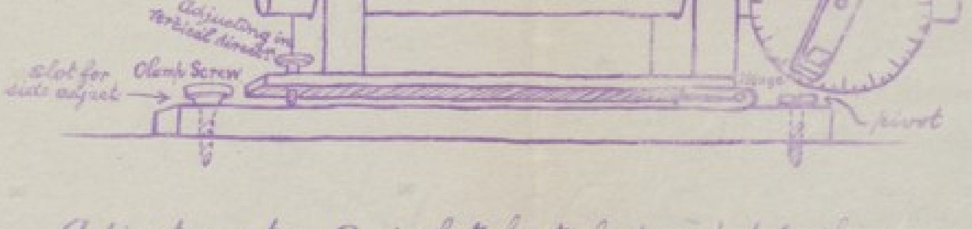
R 6486a. Wt. 320.

Fig. 1



Adjustments: The two sights should point to the same distant object.
Plane of azimuth circle to be roughly levelled.
(It might be well to provide facilities for a third pair of sights)

Fig. 2

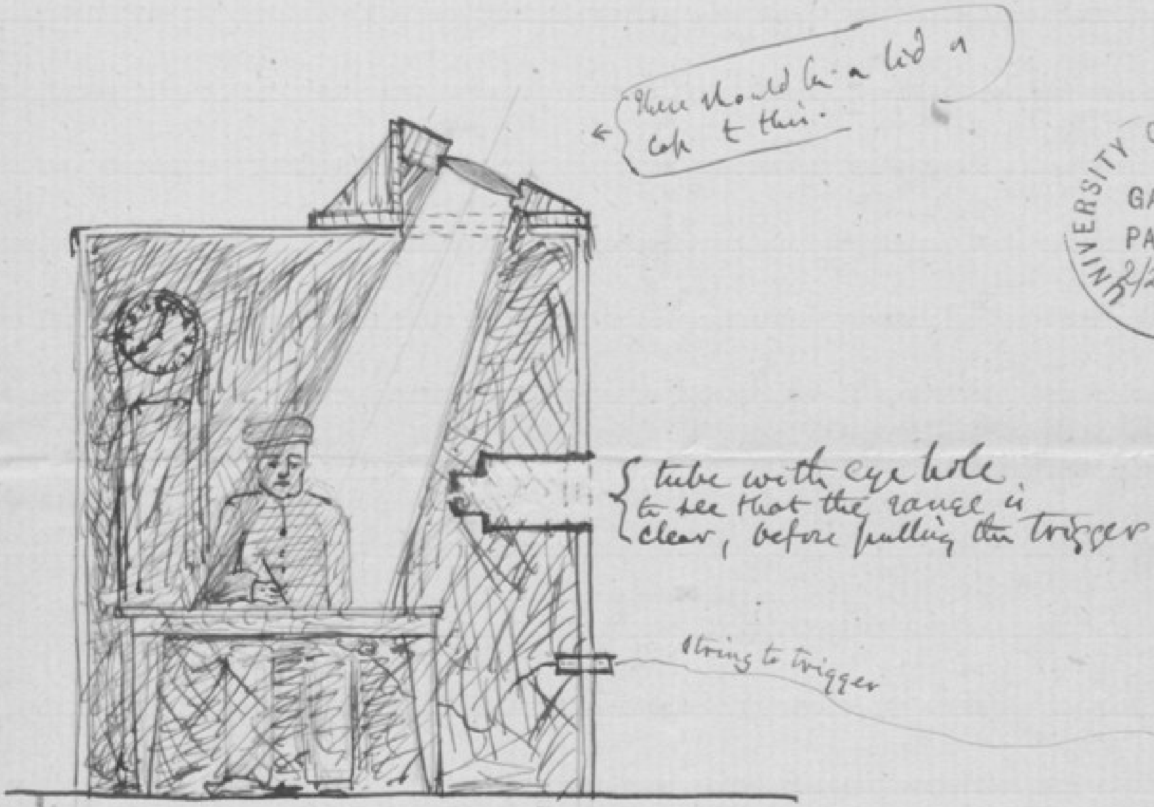


Adjustments: Axis of tube to be pointed to the corresponding instrument at the other station.

Reading should be 0° when the sights are directed to the other station – apply difference as index error.

Camera obscura for smoke-cloud.

to enable one man to fire gun & make all the necessary observations - F Galton about 11/84
see description on opposite page



Time of appearance
sound heard

a point with the pencil. When he hears the burst, he makes a short curved cross line x...........)....   and disregards the next tick if ~~it~~ comes too quickly after the burst. So he goes on pointing each second until the cloud disappears, or leaves the limits of the table ~~paper~~. The track on the paper will be the horizontal projection of the path of the cloud on the plane of the horizon. Knowing the focal length of the lens ~~the angular~~ ~~the vertical height of the [illegible] all directions can be tabulated~~ the scale of the projection can be calculated

A lens (which need not be achromatic) of 5 or 6 feet focus, is set in the roof of an otherwise dark hut. Its optical axis points to the part of the ~~place in~~ sky where the shell is expected to burst & consequently makes an angle of 67° with the horizon. The image of that part of the sky is thrown on a ~~sheet of white paper on an~~ horizontal slate table [I find by experiment that the distortion is inconsiderable under these circumstances] The paper is held in place by a hinged frame shut down upon it, which in the act of shutting pricks holes at the 4 cardinal ~~quadrants~~ with the compass (true bearing) marked on it points that at the N being double

There is a common tube with an eye hole in the wall of the hut to see that the space is clear

A clock is in the hut, that ticks seconds loudly, and a string passes through wall of hut to trigger of gun.

When the gun is loaded & pointed, always in the same direction, the observer goes into the hut and watches the image of the sky. As soon as that part of it where the shell is expected to burst, is clear, he looks to see that the space ~~sky~~ is clear & [illegible] pulls the trigger. ~~When~~ On the puff showing itself he marks the place on the ~~image with a~~ ~~paper in pencil~~ with a cross. At each tick of the clock not counting the one immediately after the puff is seen, he makes

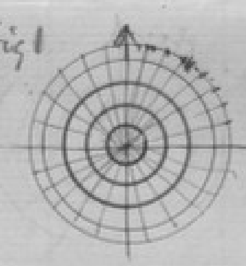
42, RUTLAND GATE,
LONDON, S.W.

Camera, for use in measuring the height (and direction and rate of movement) of clouds

It is adapted to the dry process, which I propose to employ because the cameras will sometimes be used at a distance from the observatory and because many plates may ~~[illegible]~~ be wanted, the consecutive preparation of which by the wet process would be inconvenient & would require assistance

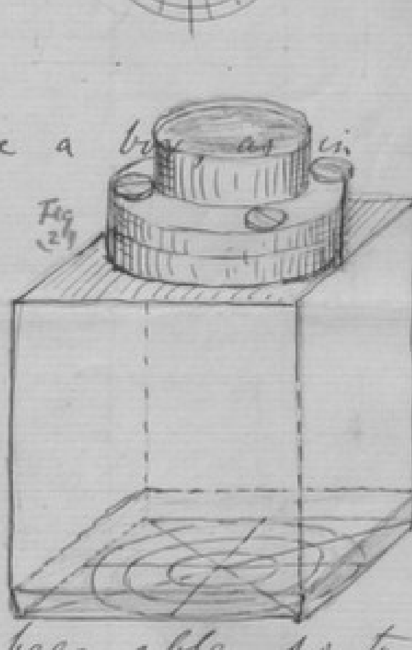
I propose that as ~~[illegible]~~ each picture is taken, a scale of altitudes and azimuths shall be simultaneously photographed upon it, together with any other data such as the number of the camera, the place, &c as may be desired. The scale will consist (as is fully shewn in Fig 1) of fine lines, radiating from a centre that accurately corresponds to the zenith point of the picture, and of a series of fine concentric circles round that centre, whose value in degrees of altitude shall have been determined. One of the radial lines is marked with an arrow head and will shew the direction of the meridian.

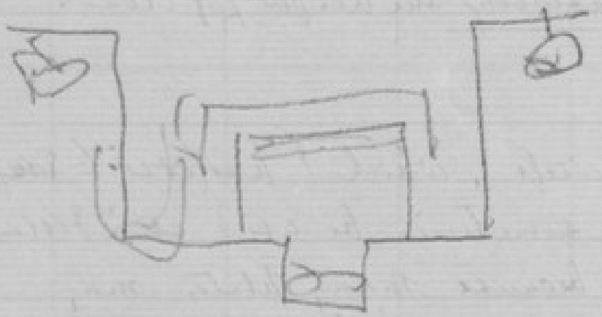
Fig 1



To produce this effect, suppose a box, as in fig 2, (in which the sides are only indicated by dotted lines) to have a flat bottom of thick plate glass, on the lower surface of which the scale fig 1, is engraved, and to have a photographic lens set in the top. The engraved scale is to be adjusted once for all to ~~must be at~~ the solar focus of the lens. Let ~~[illegible]~~ us now suppose that we have already been able so to adjust the verticality of the apparatus that the

Fig 2





the image of the zenith shall fall on the centre of the engraved scale, and that the north and south radial line of the scale shall be correctly placed, (I will shortly explain how all this may be effected) Then, if we clasp in succession any number of sensitised plates, with their collodionised surfaces upwards, against the engraved glass bottom, the required scale will be photographed on each of them, simultaneously with the clouds.

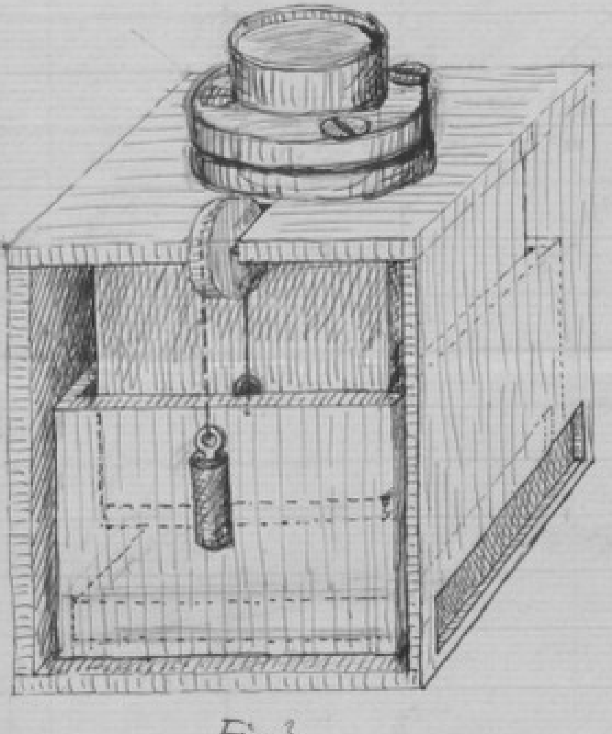


Fig 3

Fig 3, shews the arrangement for introducing a sensitised plate & lifting it up to touch the engraved glass scale. The "camera", by which word mean that part of the apparatus only, which was shewn in Fig. 2., is secured within a box much larger than itself, leaving a vacant space round it both at the sides and below. One of the sides of the box has been removed in Fig 3, in order to shew the internal arrangements. It will be observed that a deep tray or lift surrounds the bottom of the "camera" & that it is supported by counterpoises, attached to cords passing over pullies. These counterpoises lift the tray & press whatever is inside it against the glass bottom of the camera. When the counterpoises are raised by the hand, the lift descends to the bottom of the box by its own weight, & in that position an aperture in its side for inserting the plate holder lies opposite to a similar aperture in the outer box. All that the operator has now to do, is to raise the counterpoises with his hand and to hook ~~them~~ out of the way to hooks on the side of the box. Then he inserts the plate-holder through the side aperture, & withdraws the cover of it. ~~He~~ then he sets free the counterpoises upon which the lift rises and applies the sensitised plate flat against the engraved glass. The force that urges it upwards is the excess of weight of the counterpoise over that of the lift and it can be regulated to a nicety, so that there need not ~~cannot~~ be the least fear of injuring the very tough film on the sensitised plate.

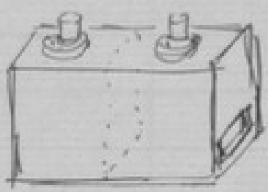
As regards adjustments. After levelling the top of the box, still keeping the ~~[illegible]~~ theodolite telescope in a vertical position looking down upon the lens, ~~then~~ screw the adjusting screws in the collar of the lens, (seen in Figs 2 & 3,) until the central point of the engraved scale viewed through the lens is intersected by the cross wires of the theodolite. Then whenever the ~~surface of~~ top of the box is level, the adjustment for verticality ~~altitude~~ will be secured

To adjust for azimuth:-- Set ~~the~~ theodolite, so that its vertical circle shall lie ~~is~~ in the plane of the meridian and in such a position that when its telescope looks vertically downwards it shall look ~~view~~ into the lens of the camera. The observer will then view the engraved scale as if it were a distant object. Now turn the box until the meridian line in the engraved plate ~~[illegible]~~ is parallel to the vertical wires of the theodolite.

To adjust for verticality:--

To obtain a scale for the circles of altitude (adopt Professor Stokes' method)

I have thus far described a camera suited for taking a single view on the same plate but considering that we shall always want two views with a brief interval between them, in order to obtain the direction & rate of movement of the clouds, I should recommend a double camera & the use of plates of the size of the ordinary stereoscopic plates.



Francis Galton

42 Rutland Gate
Oct 5 1877

10 July 1881

University Museum,
Oxford.

Dear Galton,

I return Captain Noble's letter, which is very interesting. I hope that you and he may be able to devise some arrangement which would come within our means.

I have never heard

of the Japanese "day fire works". I should not be surprized if the permanency is due to vortex-motion, which manages to disguise its ring form wonderfully well.

Ever very truly yours

Henry J S Smith

Jesmond Dene House,
Newcastle on Tyne.

2 Jul 1881

Dear Mr Galton

I have your note of the 1st inst. & do not think that there would be any difficulty in doing what you desire. but I fear that the expense might perhaps be a good deal more than you anticipate.

I have not attempted to calculate the height to which a projectile would rise, as we have no data available for such a purpose - but I do not suppose you are very much out in your guess that we should have no great difficulty in the other questions connected with the gun proposition if you do not think the costs I have named prohibitory.

Very sincerely yours
A. Noble

F. Galton Esqre F.R.S.

most economical, but I doubt if we could give a cloud of smoke sufficiently large & durable for your purpose in any gun smaller than a 40 Pr & a 6" gun would be better.

To give you a rough idea as to cost. I should say that the cost of the gun & its mode of mounting would not be taken at less than from £400 to £500. & as you have to provide means for firing the shell at its maximum Elevation you can not estimate the cost of each individual round at less than £1.

I shall be very happy to look into

in giving to a projectile a vertical Elevn of about 2 miles –

(The difficulties in the way of an approximate calculation are (1) the variation in the law of resistance of the air with respect to the velocity (2) The variation in the density of the air with reference to the height from the Earth's surface)

The mode of mounting the gun would have to be special & we suggest that the gun would be fired at an angle of 75° Elevn which would probably be the most convenient angle – Special modes of absorbing the recoil would have to be considered, but this would offer no great difficulty.

The smallest gun that would be used for the purpose would of course be the

most

Jesmond Dene House,
Newcastle on Tyne.

23 July 1881.

My dear Mr Galton

I have your letter of yesterday's date & shall be very glad to carry out the experiments you desire.

I think it may suit very well for you to come down here to see some of the Expts. from the Brit. Assn. meeting, & perhaps it would be best to make the Experiments over the sea.

I.

I do not think the "Ring" would help us much—

We have to produce as dense & durable a mass of smoke as we can & when the sky is a dull grey, it will be difficult to see at a great height.

Very sincerely yours.

A. Noble

F. Galton Esq F.R.S.

&c. &c. &c.

LONDON OFFICE, 8, GREAT GEORGE STREET WESTMINSTER S.W.

ADDRESS
SIR W. G. ARMSTRONG & Co
ORDNANCE DEPARTMENT,
NEWCASTLE on TYNE

Elswick Works,
Newcastle upon Tyne,

TELEGRAPHIC ADDRESS
"ELSWICK, NEWCASTLE"

10,058.
ORDNANCE
DEPARTMENT.

7 Jany 1882

Dear Galton

I have your letter of the 2nd inst. & having some further points to determine I had another trial made on Thursday last.

On the first trial, for reasons with which I need not trouble you, the attempt to determine the height of the burst by the measurement of 2 angles failed, &, with a small fuze, there will always be considerable difficulty with this

The time taken by the sound to return was missed on the 1st occasion but was 9.7 secs. & 9.8 secs. on the other two occasions — The shell had not reached its culminating point — The angle above the horizon of the burst on all 3 occasions was as nearly as possible 62° —

Assuming the velocity of sound at 1090 f.s. the above data give the height of burst at about 9450 ft.

You will understand that if you fire at an invariable angle of Elevⁿ the approximate height of the burst will in all cases when once certain constants are determined, be given by a simple observation of the time of flight.

The day was very stormy though bright

method — It then occurred to me, as the velocity of sound is practically independent of the density that perhaps the best way to determine the height of the burst was to take the time the sound took to come back & at the same time to take the angle of Elevation from the gun.

On this second day we fired 8 Rounds but passing over some which were made to satisfy me as to the ~~value~~ description of time fuse to be employed I will come to the more important Rounds.

The gun was fired at an angle of 75° Elevn; it would not be safe to fire at a higher angle from the danger of some of the pieces of the shell returning on the operators.

The time from the firing of the gun to the bursting of the shell was respectively. 13·9 secs., 13·9 secs. & 13·6 secs.

& the cloud of smoke can be seen without difficulty for a considerable time.

I shall be in London on Tuesday & Wednesday & shall be glad to see you to answer any questions or arrange further proceedings.

Believe me
very sincerely yrs.
A Noble

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

LONDON OFFICE, 8, GREAT GEORGE STREET WESTMINSTER S.W.

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TELEGRAPHIC ADDRESS
"ELSWICK, NEWCASTLE"

ORDNANCE
DEPARTMENT.

1 Feb. 1882.

My dear Galton

You shall have the report tomorrow. I would prefer to address it to you & shall do so, but shall send it to the care of the Met. Meteorological Council —

I have been very unwell recently.

Yours very faithfully
A Noble

F. Galton Esq. F.R.S.
42 Rutland Gate
S.W. London

Camera for measuring
height of clouds

Letters on it from, Stokes

Sir G G

Memorandum on the plans for a Cloud photographing Camera proposed by Mr Galton.

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1. Assuming that it will not be requisite to work with wet plates, I approve of the principle of marking the fiducial marks on a picture relative to the object-glass. This may be done as proposed by Mr Galton since a dry plate may touch another plate.

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2. As to the number of fiducial marks, I contemplated measurement of the developed plate under a suitable instrument. In this case the fewer marks the better, so as to leave the image of a cloud as nearly undisturbed by anything extraneous to distract the observer's attention as possible. In this case it would be well to have no marks beyond a single cross + Probably this would be rather the more accurate; but approximately estimation by means of a spider's web of wires would be the more rapid. Rapidity is an important point in observations which

have to be taken statedly, but does not signify much in those which have to be taken a few times to elicit a fact once for all. This latter is what I had contemplated, but I think it likely that the plan may prove useful for habitual employment, and therefore rapidity will be an object.

3. Might not a spiral spring be handier than a weight?

4. Adjustment for zenith.

In the arrangement proposed by Mr Fulton, if I rightly understand it the top of the bar is to be levelled [this implies a permanent circular level fixed to the bar, or else, which would be less convenient, the use of a detached level, and implies also that the bar rests on three levelling screws] and the adjustment is to be effected by giving a lateral motion to the object-glass by means of adjusting-screws. This lateral motion is given once for all, and in future in order to make the instrument point to the zenith it is sufficient to level the top.

I don't like the lateral adjustment of the object-glass, on the ground that the object sought may be attained much more simply by furnishing the circular level with adjusting-screws. When the theodolite points to the nadir, the centre of the bubble is brought to the crosswires by means of the levelling-screws on which the base stands, and then the level is adjusted by *its* screws for the bubble to stand in the middle. Henceforth to adjust for altitude (i.e. make the camera point to the zenith) we have merely to bring the bubble to the centre by means of the levelling-screws.

5 Adjustment for azimuth.

If this be done ab initio every time the inst. is used, instead of adjusting once for all the graduation of a magnetic needle, and hence forth adjusting by means of the needle, it pretty well restricts the use of the inst to a fixed observatory or quasi-observatory, and requires a theodolite for each camera — rather a costly addition. I think adjustment by a needle would be quite as accurate as the other parts of the process demand; and the cost of a needle with an adjustible mark to set opposite to it would be a trifle compared with the cost of a theodolite.

I doubt if the theoretical superiority of making the adjustment each time by means of a theodolite would justify the increase of cost. It is one thing to require the loan of a theodolite for an adjustment to be made once for all: it is another to demand that each camera shall have a theodolite married to it.

6 Double Camera?

For accuracy's sake it is well to allow time for a few substantial changes of angular position in a cloud. We should want I think a second slide, but I would not go to the expense of a double camera unless experience should show that it was desirable.

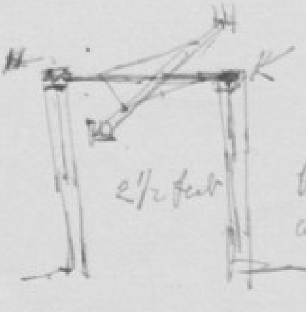
As to difference of time of exposure, it would be easy to agree beforehand that in the first experiment each of the two exposures should be say for 3s, in the second for say 10s, or whatever experience might show to be the proper thing or thereabouts. A double camera would not therefore be demanded for *this* purpose.

G. G. Stokes

Cambridge Octr 8, 1877.

It is ~~probable~~ possible that it would be found most convenient to build several pairs of brick pillars at various distances apart (~~carefully ascertained~~) & to mount the rude theodolites on the two that seemed the most suitable on each occasion; the angle between the drift of the wind & the pillars being recorded. Provisionally the trials would be made with theodolites on tripods at measured distances.

F.G.



AK has to be levelled by screwing up or down a plate at K on which the V is placed.

Height of Clouds (Postcroft) March 28/83

The flagstaff, chimney &c need not have a real existence, It may be ~~replaced by~~ optically supplied, by means of a vertical wire in each of two collimators (transit instruments theodolites &c) placed at A & B respectively & so converging that the vertical line would occupy the position where the flagstaff would have been.

The simplest & probably the most convenient arrangement for a collimator would be like a light gun barrel with sights, freely moveable on trunnions in a vertical plane with an index pointing to a roughly divided circle, reading to degrees or two degrees.

The base AB should subtend at least 30' from the cloud that is AM should equal 120 AB (or thereabouts) — Take it = 100 AB

~~that is This allows~~ If the parallax is too large, serious error arises from the changing outline of the cloud during the time of obs^n. If too small, serious error arises from the want of definition of the cloud ~~causing~~ as the uncertainty as to the time of contact then becomes a considerable fraction of the time of transit.

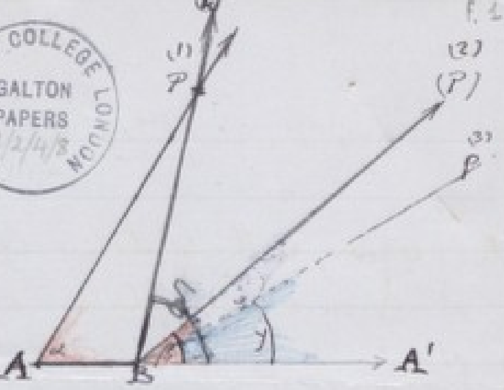
AC might be taken at about $\frac{1}{10}$ AB then even if the motion of the cloud ~~were~~ at the rate of 60 miles per hour the observer could run from A to B or vice versa in time for the observation

There should be not one only but 2, 3 or more sights to enable the angular velocity to be determined at A or B and to give alternative values for AC according to circumstances

It is

Dear Professor – this seems reasonable? F.G.

Distance of Cloud



The Observer, with watch & sextant, stands at A on a level plain, over which the clouds drift parallel to AA′

(1) At A, he takes the altitude of some recognisable point P in the cloud; that is the ∠ PAA′, call it α, & he notes the time by watch.

(2) He walks, (or drives, &c) towards A′ counting his paces, until he has arrived at some convenient, known distance, say at B, where he again takes the altitude of P & notes the time by watch. Call the altitude β, and the time elapsed since obs. (1), t seconds.

(3) Standing at B, after a further elapse of time, s seconds, he again takes altitude of P, call it γ. From these data, (s, γ and β−γ) he calculates what the altitude of P would have been at B, if observed t seconds previously to obsn (2). Call this revised altitude δ. He thus puts himself in the condition of having observed (1) & (2) simultaneously, & he calculates AP from ~~the~~ data of base AB & the angles at either end of it, viz α & 180°−δ

The method wd fail, if the clouds did not move horizontally or uniformly, or if they changed their shapes so rapidly that a base AB of adequate length was impracticable. Also, if they moved much faster than the observer, there would be risk of error in more than one way; ~~[illegible]~~ In these cases, repeated obsns would yield different results; whenever they always concurred they could be trusted.

Of course (3) need not be made by observing the same point P; any other point in the same plane of cloud ~~of~~ which the altitudes were determined at beginning & end of obsn, would give the requisite data.

F. Galton

42 Rutland Gate March 29/83

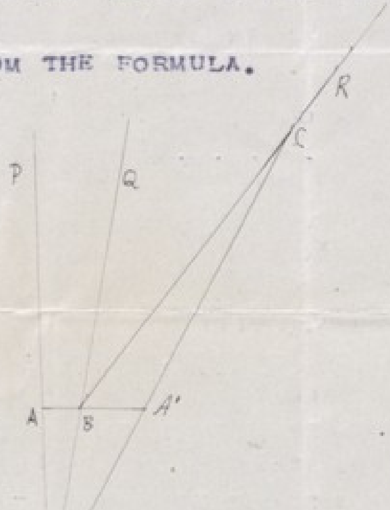
f. 2r

LENSFIELD COTTAGE, CAMBRIDGE, 31 MARCH, 1888.

DEAR MR. GALTON,

I RETURN YOU YOUR PROPOSAL ABOUT THE HEIGHT OF THE CLOUDS. IT SEEMS TO ME TO BE QUITE A WORKABLE THING. ITS ACCURACY WILL DEPEND MAINLY ON WHAT LENGTH OF BASE, AB, YOU CAN AFFORD TO ALLOW WITHOUT CONSUMING SO MUCH TIME THAT THE CLOUD SHOULD CEASE TO BE IDENTIFIABLE IN THE THREE OBSERVATIONS.

THE METHOD LEADS TO A SIMPLE GEOMETRICAL CONSTRUCTION, WHICH MIGHT BE USEFUL FOR INDICATING TO THE EYE THE CONDITIONS OF ACCURACY, ~~THE~~ THOUGH THE ACTUAL HEIGHT WOULD NATURALLY BE GOT RATHER BY CALCULATION FROM THE FORMULA.



LET AP, BQ, BR BE THE LINES OF SIGHT. PRODUCE AB TO A', TAKING BA':AB:: $t_2 : t_1$, t_1, t_2 being the intervals of time, SO THAT A' IS WHERE THE OBSERVER WOULD HAVE BEEN AT THE THIRD OBSERVATION IF HE HAD WALKED STRAIGHT ON AT THE SAME RATE. PRODUCE PA, QB TO MEET IN O, AND JOIN

OA', PRODUCING IT TO CUT BR IN C; THEN C IS THE PLACE OF THE CLOUD AT THE THIRD OBSERVATION.

THE FORMULA IS

$$h = \frac{t_2 a}{t_1(\cot\gamma - \cot\beta) - t_2(\cot\beta - \cot\alpha)}$$

OF COURSE THE DENOMINATOR IS THE TICLISH SMALL QUANTITY WHICH IS LIABLE TO BE VITIATED BY ERRORS IN THE ANGLES ARISING FROM THE VAGUENESS AND CHANGEBILITY OF THE OBJECT. THE TIMES WE MAY DEEM TO BE KNOWN EXACTLY. IF THE FIRST OBSERVATION WERE MADE BEFORE THE CLOUD GOT TO THE ZENITH, THAT WOULD PERMIT OF TAKING A LONGER BASE AB.

YOURS SINCERELY,

G. G. Stokes

FRAS. GALTON ESQ. F.R.S.

P.S. BY TAKING TWO OBSERVATIONS OF ALTITUDE BEFORE THE CLOUD CAME TO THE ZENITH, THEN WALKING, THEN TAKING TWO MORE, NOTING OF COURSE THE FOUR TIMES OF OBSERVATION, WE SHOULD HAVE A CHECK. THIS WOULD GIVE FOUR - EQUIVALENT HOWEVER TO ONLY TWO DISTINCT - DETERMINATIONS.

5) A good sight may be taken of the shot in the cloud by one of the angular instruments in 5 seconds

Putting these data together, each observer has 25 seconds to get to his station during which he moves at 5½ miles per hour. That is to say the stations ~~are~~ may be severally about (25×4.5×1.5 or) 200 feet distant from the central station and 400 feet from one another.

Again, as the error of the result must not exceed one tenth of the true value, the parallax of the base must be at least 10 × $\frac{1}{4}$ of a degree = 2½ degrees. Now 400 feet subtends that angle at a distance of about 25×400 = 10.000 feet.

It is obvious therefore that this method ~~is serviceable~~ may be adopted for the measurement of ~~low~~ clouds, under almost any circumstances when they are ~~nearly~~ not far from the zenith (are not very high, ~~if they~~) ~~if~~ exhibit any recognisable points at all. Where the clouds are more durable in shape & when the observer can use a tricycle or other rapid means of locomotion the base might be increased at least four fold and clouds at a distance of 40 000 feet might be ~~deter~~ determined as accurately as those of 10.000 feet under the former supposition

f. 4v

Method of determining the distance and height of clouds, ~~their height~~ and the direction & rate of their motion

I suppose three observers ~~at~~ & that these are three stations in a line, A C B, C being the central one. At C ~~there~~ is placed an instrument (fig 1) that I call a "Finder" which is in principle a rude theodolite with two parallel ~~not telescopes but~~ pairs of sights. At A & B there are two very simple angular instruments (fig 2). All three observers stand at first at C where two of them look simultaneously through the finder, conferring and turning it about until they have fixed upon some spot of cloud or of blue ~~sky~~ interspace, as suitable for triangulation. They then hasten to their posts, the one to the left, to A & the other to the right, to B, where they quickly adjust their instruments upon the spot of cloud and following its motion, until they are simultaneously signalled to stop ~~simultaneously~~ by a whistle from the third observer at C. We then read off.

The third observer occupies himself in ~~taking~~ making a reading off ~~for~~ an observation of altitude and azimuth of the same or of an adjacent part of the clouds while the other two are hastening to their posts, & after having given the signal whistle, he repeats the process. Thus all the necessary data are obtained.

I assume that,

(1) Clouds change their shape so rapidly, that a spot in them may cease to be recognizable after 30 seconds, though sometimes, especially in cirrus, their shapes are much more permanent.

2, The maximum error of ~~determination~~ observation, ~~of~~ may be set down as $\frac{1}{10}$ of a degree in determining the parallax of the base as seen from the cloud

3, The ~~accuracy of~~ determination of distance of the cloud would be usefully accurate if the error did not exceed one tenth of the true ~~amount~~

4, The observers may run without distress to their stations, (during these 25 seconds), at the rate of 5½ miles per hour

I propose to use 3 observers & three instruments, one of which is a Finder Fig 1 placed at a middle station through which two observers look simultaneously along parallel sights ~~which~~ and which they move about while they confer until they have selected a recognisable [illegible]. They then separate & hasten one to the one & the other to the other to their respective stations where their respective angular instruments Fig 2 are placed and whence they take their obsns simultaneously of the angle between the cloud spot & the other observer, as guided by a signal whistle from the 3rd obsr. who remains (they do so) at the middle station.

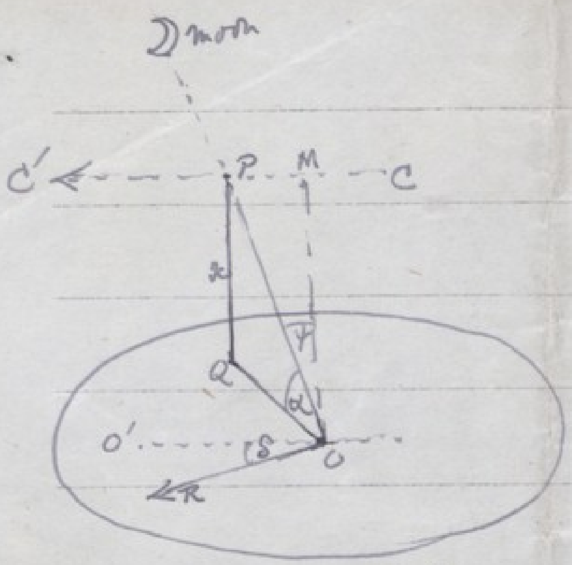
This third observer has the further duties of making & reading off an observation of the same or an adjacent cloud spot [illegible] while the observers are hastening to their station & of repeating the operation after giving his signal whistle. He uses the Finder for the purpose which is ~~roughly~~ mounted on the principle of a theodolite as shown in the sketch

The angular instruments Fig 3 are tubes ~~to~~ act as telescopes or plain & furnished with sights which are pointed at one another so as to lie in the same line. Each tube ~~is supported~~ rotates round its axis and bears a graduated circle set flat against one of its ~~free~~ ends, which projects beyond the support. An arm ~~fitted~~ with sights, ~~moved~~ which is fitted to the graduated circle.

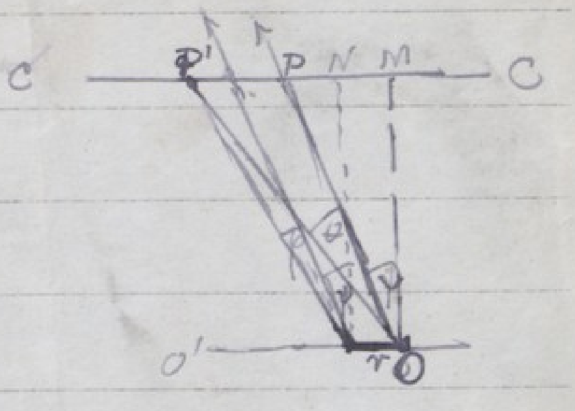
The instruments are not supposed to be of refined make but to read off to 10' only, allowing 5' to be estimated. They are furnished with sights not telescopes & the easiest sight to work is the simplest form of collimator

For sights I use ~~the~~ a collimator of the simplest kind, namely a lens of some 6 inch focus whose upper edge is free & eye piece. It is much easier to ~~take~~ ~~adjust~~ direct such an instrument ~~[illegible]~~ if both eyes are ~~used~~, ~~one~~ kept open, than it is to take aim with a ~~gun~~ rifle furnished with ordinary sights.

Each of these consists of a tube revolving in ~~&~~ supports, having a graduated circle ~~with an arm carrying sights~~ fixed flat against one end of it and an arm carrying sights moving round the graduated circle. The tubes serve when a sight is open as telescopes, & the instruments are thereby adjusted so that their tubes lie in the same line. Consequently ~~the angle~~ when the sights of the two instruments are directed simultaneously to the same spot they register the basal ~~from the two~~ angles of the triangle of which the distance between the stations is the base & the distances ~~that~~ between the stations & the spot observed are the sides.



(1)



(2)

Fig (1) O. the point where the observ: commence.

The area enclosed by ellipse Fig 1 is the ~~plane~~ enclosed by of the horizon seen from O

P is a point of cloud seen traversing the moon in direction CC′

draw OO′ parallel to CC′. and OM ⊥r to CC′ – MOP = ψ

OR is the direction in which the train was making ∠ δ with OO′. MOP is given = ψ

Altitude of moon above horizon = α

Fig (2) is drawn in plane of OCC′

Given. In a brief period of time t, the train travels a distance R and the cloud travels a distance PP′, then that ~~train~~ portion of the train's motion that is resolved along OO′ = r. {= R. sin δ}

the angr: motion of P during t to observer at O = θ – to observer in train ~~who has arrived~~ during the same time = φ

$PM = PN + NM$, ~~or~~ $OM \tan(\theta+\psi) = OM \tan(\varphi+\psi) + r$

$$OM = \frac{r}{\tan(\theta+\psi) - \tan(\varphi+\psi)}$$

$OP = OM . \sec\psi$ ~~Bq~~ $x = OP \sin\alpha$

$$x = \frac{r \sin\delta}{\tan(\theta+\psi) - \tan(\varphi+\psi)} \cdot \frac{\sin\alpha}{\cos\psi}$$

7h. March 26/83.

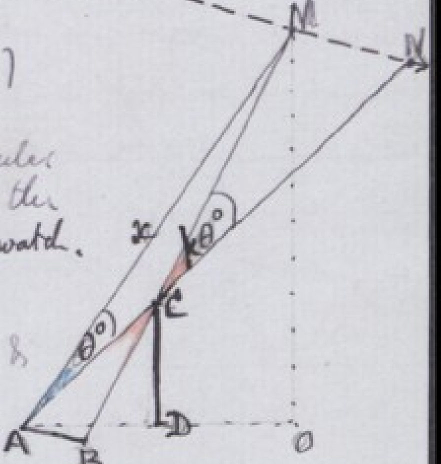
Distance of Clouds (also height & drift)

CD a tower (flag staff, tall chimney &c) of known height say 100 or 200 or more feet.
AB a short measured base parallel to drift of clouds.
AD is known. Consequently ∠ ACB is known (also CAD)

Then an observer at the base line can measure

(1) angular velocity of cloud as seen from A, either by an angular instrument ~~& stop watch~~ or by finding the angular breadth of the tower as seen from A & using that as his scale, & by a stop-watch.

(2) angular velocity of cloud as it would be seen from C. He observes a point in the cloud in the line BC produced, call it M, & then stepping to A notes how long ~~it~~ the same point takes to arrive at N, in the line AC produced.



Consequently he knows the ratio of the two small angles MCN & MAN, &, as he also knows the distance AC, the distance of the cloud, MA or NA, can be found. Probably this method would give approximately fair results if MA was not more than 10 AC. Hill tops would serve well for C & give a large value to AC.

Example:—

In any ~~given~~ brief time t, the cloud will have travelled through a small space, which will subtend θ° to an observer at A, and φ° (= kθ°) to an observer at C. Let distance of cloud (AM or AN) be called x

$$x . \theta^\circ = (x - AC)\, k\theta^\circ$$

$$x = AC \cdot \frac{k\theta^\circ}{k-1} .$$

(Height of cloud = x. sin CAD. & rate of motion $\left(\frac{MN}{t}\right) = \frac{x \sin\theta}{t}$

Note. This method seems excellently adapted to determine distance, size & rate of sailing of ships, when their course is parallel to the shore (or in a direction that may be approximately guessed), if the observer is a few hundred yards inland & sights them by marks in the cliff ~~edge~~ or shore &c.

ACB = 100

let cloud as seen from C travel through these 100' of arc in 8 secs

let cloud as seen from A travel ~~th~~ through 90' of arc in 8 secs

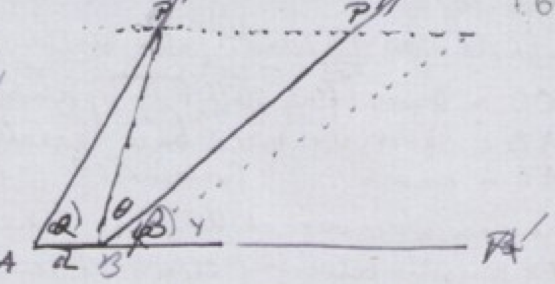
$$\therefore \theta : k\theta :: 9 : 10$$

$$k = \cancel{x} \cdot \frac{10}{9} \qquad \frac{k}{k-1} = \frac{\frac{10}{9}}{\frac{1}{9}} = 10$$

$$x = 10\, AC$$

Distance of cloud

Observer, with a ~~stop~~ watch & sextant is on a level plain ~~walks with in same~~ over which the clouds are drifting parallel to AA' ~~from A towards A which is the direction in which the clouds are drifting~~. (1) he takes, at A, with ~~the~~ a sextant the ~~altitude of~~ that is the angle PAA' (call it α) ~~a point~~ P in a cloud above AA' and he notes the time ~~that is α~~



(2) he walks on towards A' ~~for time t~~ ~~over a measured distance~~ counting his paces until he arrives at some convenient distance ~~some point~~ B where he again takes the altitude of ~~the same spot~~ P that is β. & notes ~~the elapsed~~ time again t since obs: (1) call time ~~since~~ t.

(3) standing at B he ~~observes angular velocity of cloud say of same progress of same spot~~ he again takes altitude of same spot after a further lapse of t seconds (call it γ) whence he can calculate what the altitude of the point would have been t seconds previous to observation (2) that is at the moment of taking (1). By ~~doing so the triangle~~ this he ~~throws it~~ puts himself in the position of having made (1) & (2) simultaneously — call this revised altitude γ. Then the ~~the~~ triangle of which the base AB & the angles at either end of it α & 90°−γ are known & of which the sides are the distance of ~~the cloud~~ P from A & B at alts α & 90−γ respectively. ~~Hence the~~ height AP is AB sin θ & BP cos γ

If clouds are not moving uniformly or if they changed their shape fast, this method would fail, but ~~the concurrence of~~ the successive obs of it would ~~in that case~~ & successive observs would not concur. If the obs do concur & their results, the results might be trusted. Again if the drift of the clouds was very rapid there would be ~~difficulty~~ risk of error ~~owing to the difference~~ ~~of any bias~~

479

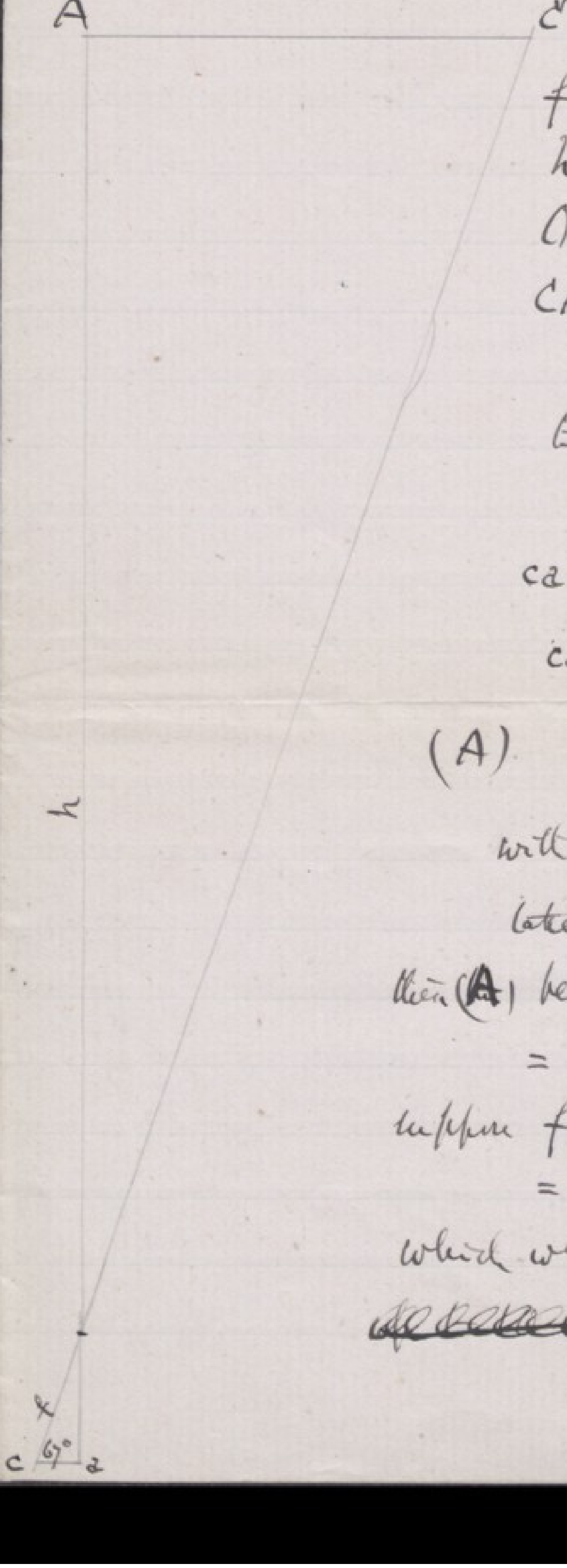
Clouds

Capt Noble &c

1884

Shell firing
for smoke cloud
Hat to observer

F. Galton April 12/04



f = focal length of lens in feet
h = height vertically, of cloud
Oca = 67° (sin 67° = 0.92)
CA a portion of the path of the cloud supposed parallel to ca

to find ca in terms of CA

$$ca : CA :: f.\sin 67^\circ : h$$

$$ca = \frac{CA.f}{h}.\sin 67 \text{ (in feet)}$$

$$(A) \quad = \frac{12 \times CA.f}{h}.\sin 67^\circ \text{ (in inches)}$$

with fuse 4.8 inches h = 10,000 feet
take CA = 1000 feet
then (A) becomes 1.2 × f × 0.92
= 1.104 × f (in inches)
suppose f = 9 feet
= 9.936 or say 10 ~~[illegible]~~ inches,
which wd be a very convenient size. ~~[illegible]~~
~~[illegible]~~

Clouds

Distance de 1

avril 1883

Clouds

20°)
3.837303
co 9.972986
3.810289 6461
9.534052
3.344341 – 2210

55°)
3.837303
9.758591
3.595894 3944
9.913365
3.509259 3230

65°)
3.837303
9.625948
3.463251 – 2906
9.957276
3.420527 – ~~2755~~
2633

70°
3.837303
9.534052 ~~2400~~
9. 371355 2351
9.972986
.344341 2210

15°)
3.837303
9.984944
9 822247 6641
9.412996
9.235243 1719

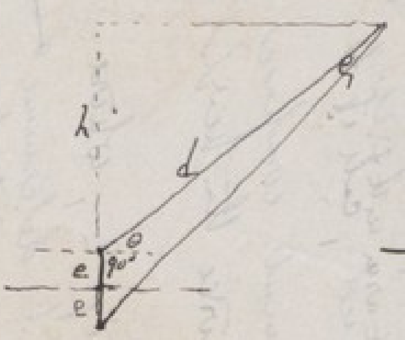
10°)
3.837303
9.993352
9.830655 6771
9.239670
9.070325 1176

5°)
3.837303
9.998344
9 835647 6849
8.940296
8.775943 871

75°)
3.837303
9 412996 1780
9.250299
9.984944
9.235243

80°)
~~3.837303~~
9.239670
9 076973 .1194
9.993351
9.070324

85°)
3.837303
8.940296
2.777599 599
9.998344
2.775943



~~log cos 52°~~ ~~log sin 52°~~

~~3.837303~~
~~9.918477~~
~~3.755980~~
4388
~~3378~~

~~3.837303~~
~~9.805038~~
~~3.642341~~
~~9.886342~~
~~3.528703~~

50°

3.837303
log cos 50° 9.808067
3.645370 4420
log sin 50 9.884254
3.529624 3385

60° 3.837303
log cos 60° ~~9.698970~~ / ~~5000~~ 3437
3.536273
log sin 60° 9.937531
9.473804 2977

$$\frac{d}{\sin\{180-\{90+\theta+\rho\}\}} = \frac{2e}{\sin\rho}$$

$$\frac{d}{\cos(\theta+\rho)} = \frac{2e}{\sin\rho}$$

as ρ is unimportant in comparison with θ and never exceeds say 3
we may put the above approximately as

$$\frac{d}{\cos\theta} = \frac{2e}{\sin\rho} \qquad d = 2e\,\frac{\cos\theta}{\sin\rho}$$

~~when ρ is be expressed in minutes and arc~~ 1′ ~~= 3442 ρ~~
$= \frac{2e}{3442\,\rho}$

~~[illegible]~~
~~[illegible]~~
or d varies directly as e and inversely as sin ρ
or, as ρ never exceeds some 3°, we may say as the arc ρ
also $h = d\sin\theta$

if e = 1 foot & ρ = 1′

$$d = 2\,\frac{\cos\theta}{0.00029}\;\frac{1}{\rho}$$
$$= \frac{\cos\theta}{\rho\,0.000058}$$

log 2 = 0.30103
log $\frac{1}{0.00029}$ = 3.53627
3.83730

θ = 25°
cos 9.95727
3.83730
3.79457
sin 9.62595
3.42052

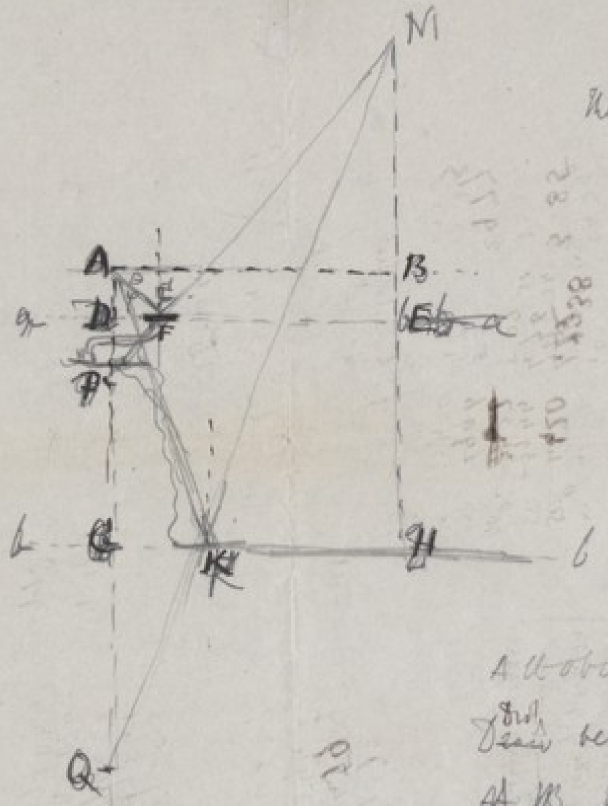
h = 2634

$$= \frac{e}{\rho} \times \frac{\cos\theta}{0.000058}\;6874$$

$$d = \frac{e \text{ in feet}}{\rho \text{ in minutes of arc}} \times \cos\theta \times \frac{1}{1720}\;6874$$

$$h = \frac{e}{\rho} \times \frac{\sin\theta\cdot\cos\theta}{1720} \times 6874$$

The 2 rt L^d Δ^s AOC α



on determining the ~~Measurement~~ of height of a cloud by observing its reflexion in ~~a cup of~~ water ~~from the~~ ~~two sheets~~ of a cup of water or other horizontal surface and in a pool ~~at below~~ at a lower level

A the observer M the observed point of the cloud

Draw verticals ~~through~~ from A & M

AB the level of the observer

by keeping the tilt of E that of a cup of water (or a ...) so supported that the eye can look at the water below

GH the level of the pool.

Take AP = 2AD & AQ = 2AG

Join PM cutting DE in F

& QM cutting GH in K

then the reflexions of M in the cup is seen in direction of AF & that in the pool in direction AK.

The angle of depression BAF (= AFD or MFE) is roughly measured by help of ~~a~~ arm with sights that is moving in a vertical ~~plane~~ graduated circle

& the angle FAK is observed by a sextant

Since AFD = MFE the two right angled Δ^s triangles AFD & MFE are similar as BAF = EMF

~~Then by~~ similarly ∠GAK = ∠KMH.

consequently ∠ GAF − GAK (or KAF) = EMF − HMK (or KMF)

that is to say the ∠ FMK is ~~identical~~ with that which was measured by the sextant

& the ∠ BAF has also been measured by the arm with sights, call it θ

Moreover ~~Also~~ PQ is supposed to be known, which as AD is small compared with AG may be considered = 2DG ~~which~~ or twice the height of the cup above the pool. call it 2l

The problem ~~consequently~~ therefore becomes simplified as in Fig 2, where θ, ~~...~~ and l are given & it is required to determine d, the distance of the cloud and h its vertical height ~~above~~ from the cup of it.

f.50

f. 5v

ar. log sin 1' = 6.4637261

log $\frac{1}{\sin 1'}$ = 3.5362739
log 2 = 0.301030

log constant = 3.837303
6874

	sin	cos
25°	9.625948	9.957276
30	9.698970	9.937531
35	9.758591	9.913365
40	9.808067	9.884254
45	~~9.849485~~ 9.849485	~~9.849~~ 9.849485

45°
3.837303
9.849485
3.686788 4862
9.849485
3.536273 3438

10
15
20 4461 230 | 2210 424 801
25 6231 47 | 2633
30 [illegible]4 277 45 | 2978
35 [illegible]32 322 43 | 3230 252
40 5267 365 40 | 3386 2104
45 4862 405 | 3438
50° 4420 ~~412~~ 438 34 | 3385
55 3944 476 31 | 3230
60° ~~3437~~ 507 | 2977
65 2906 531 | 2633
70 3420 486 | 2210
75
80

25°
3.837303
9.957276
3.794579 6231
9.625948
9.420527 2634.

30°
3.837303
9.937531
3.774834 5954
9.698970
3.473804 2978

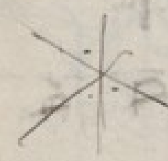
35°
3.837303
9.913365
3.750668 5632
9.758591
3.509259 3230

40.
3.837303
9.884254 5267
3.721557
9.808067 3386
3.529624

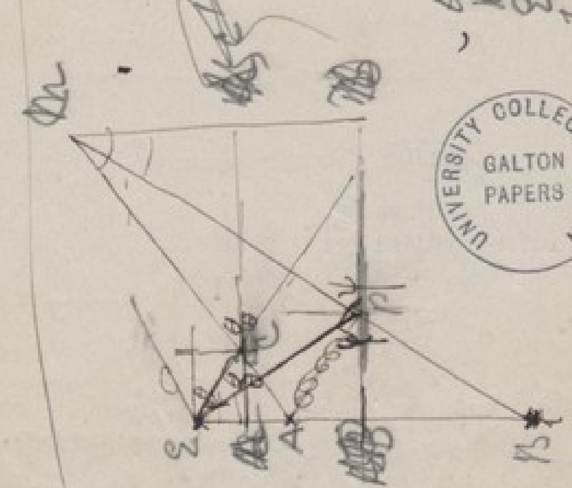
1 had 18 feet
× 30'
× 25° alt

L = 2634 × $\frac{18}{30}$ $\frac{6}{10}$

= 1580,4

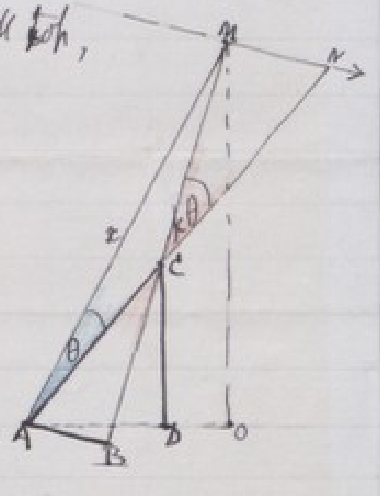


AA the level of the water in this cup (or of the horizontal line)
BB that of the water in the pond in ~~the~~ the observed point in the cloud
E the observer.
In vertical line from E take EA' = 2aEax EB = 2 CB
join AM BM.



F. 6

Distance of Clouds – (implicitly also, their height & rate of drift)



CD a tall chimney, Kew Pagoda, steeple, or flag staff on cliff or hill top, of a known height above observer, say at least 150 feet.

MN the line of drift of clouds

AB a short measured base, ll^l^ to MN

AD is supposed known, consequently both ∠ CAD & ∠ ACB.
The distance AC is supposed to be small compared with AM.

Then an observer at the base line can measure:–

(1) angular velocity of cloud as seen from A, using either an angular instrument or utilising the angular breadth of the tower as seen from A, and a stop-watch.

(2) Angular velocity of cloud as it would be seen from C, by observing from B a point in the cloud (call it M) which lies in the line BC produced, and then stepping to A and noting how long that same point takes to travel to N, in the line AC produced.

Hence he finds the ratio of the two small angles MAN, MCN; whence, as he knows AC, the value of AM (which is the distance of the cloud) can be calculated as follows:–

~~[illegible]~~

In a given brief time (t seconds) the cloud will have travelled through a small definite distance, MN, which will subtend θ° to an observer at A, and $\phi^\circ = k\theta^\circ$ to an observer at C. Let distance of cloud from A or B be x (that is to say, either MA or NA, MB or NB which may be all taken as equal.)

$$x\,\theta^\circ = (x - AC)\,k\theta^\circ$$

$$x = AC \cdot \frac{k}{k-1}$$

Height of cloud $= x \cdot \sin CAD$, and its rate of motion $= \frac{MN}{t} =$ ~~[illegible]~~ $= \frac{x\,\theta^\circ}{t}$

*

F. G. March 26/83

This problem applies to determining distance and rate of ships sailing when their course is parallel to the shore (or inclined to it by a known angle), if the observer is a few hundred yards inland and sights them by marks placed near the shore.

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*Example. Let ACB = 100′. Let cloud as it would be seen from C travel through these 100′ of arc in 8 secs, and let cloud as seen from A travel in 8 secs through 90′ of arc.

then $\theta : k\theta :: 9 : 10$

$k = \frac{10}{9}$, $\frac{k}{k-1} = \frac{\frac{10}{9}}{\frac{1}{9}} = 10.$

$x = 10\,AC.$