

(Elwell) ✓
15" HC

HARVARD-SMITHSONIAN
CENTER for ASTROPHYSICS
CAMBRIDGE, MASSACHUSETTS 02138

Address or Mail Stop 9 Ginger@CFA5 or CFA5::GINGER (617) 495-7216

7 December 1988

Mr. Russell W. Elwell
P.O. Box 146
Indiantown, Florida 34956

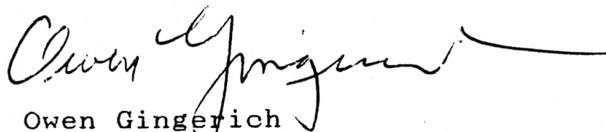
Dear Mr. Elwell:

The Great 15" Refractor saw its "first light" in 1847; for about ten years it was a twin for the largest refractor in the world. The telescope is still quite impressive on its original pier, but for quite a few years has been inoperable because of problems with the dome itself. Our intention is to restore the instrument to its 1850 splendor, removing some of the extraneous "modernizations" that mar it as a museum piece. Already in the last century the original clock drive was replaced, but there exist fairly detailed drawings from the Pulkova Observatory (where the twin instrument was located), and I hope from these that it will be possible to machine a pretty good facsimile of the original drive.

Recently I obtained a copy of the now rare and expensive publications from the Pulkova Observatory, which give the plans for the clock drive. I obtained it from an auction in Munich by a dealer who tells me that he has received the book but it has not yet been sent here to me. I assume that I will have it in a few days, at which time I will make xerox copies so that you can see what is involved.

We greatly welcome your enthusiastic opportunity to help us on this project, and we are hoping that something will work out.

Sincerely yours,



Owen Gingerich
Professor of Astronomy
and the History of Science

OG/jj

Xc: Prof. Philip Morrison
Prof. Irwin Shapiro

DEAR SIR:

Nov. 29, 1988

DEC 2 1988

PHILIP MORRISON SENT ME A LETTER

STATING THAT THERE'S A POSSIBILITY THAT I MIGHT BE OF SOME HELP IN RESTORATION WORK THAT MIGHT BE DONE ON A HARVARD COLLEGE TELESCOPE OF ABOUT 1830±.

THIS IS EXTREMELY ATTRACTIVE TO ME. I WOULD LOVE TO BE OF SOME HELP TO YOU. THE GEARS ETC. AREA ARE WHERE MY LABOR WOULD BE OF MOST HELP. DO NOT FIGURE ON ANY COST TO YOU, FOR LABOR OR MATERIALS.

AS BACKGROUND FOR MY GEAR EXPERIENCE, THERE WERE

- ① 8 ANTIKYTHERA DEVICES (GREEK ITEM PUBLICIZED BY DR. DEREK PRICE, LATE; OF YALE, @PRINCETON +) IN MUSEUMS.
 - ② I RECEIVED A 1ST PRIZE BLUE RIBBON AT ORLANDO'S NAT'L. CONV. OF N.A.W.CC. FOR MY MORE-OR-LESS COPY OF HABERMEL'S NEAT 10" Ø ASTROLABE. IT IS THE ONE ON THE COVER OF NAT. SCI. MUSEUM, ENGLAND.
 - ③ SOME 40-50 CLOCKS & CASES I'VE MADE SINCE 1978.
 - ④ A DOZEN TYPES OF ANTIQUE SCI. INST.; PROBABLY 25 PIECES, ALL THESE WERE SUCH FUN TO MAKE. SO I DO LUCK OUT.
- IF THIS PROJECT DOES WORK OUT, AND I CAN BE OF ANY HELP, I'D LOVE TO BE ASKED.

IS A COPY OF THE PLANS, DATA ETC. OF THE PULKOVA TELESCOPE AVAILABLE THAT I MIGHT SEE?

THANKS

Russell W. Elwell

Box 146

INDIANAPOLIS, IN

PHONE

305-597-2988

November 21, 1988

Mr Russell W. Elwell
Box 146
Indiantown FL
34956

NOV 23 1988

a version
for Owen G.

Dear Mr. Elwell:

How slow I am to respond to your letter of June! But that delay does not mean I did not much admire your letter; thanks.

I certainly am trying to think of something that could stimulate your nifty craftsmanship.

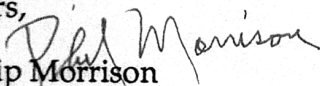
Meanwhile I have had an idea that is a little different, but might really please you. A number of the engineers and astronomers at the Harvard College Observatory have a plan to restore the old fifteen-inch refractor there, still on its granite pier after about 150 years. They are planning hard and even finding some money. I believe they would like to have a devoted historical machinist like you take on some of the gear and wheel work for the drive clock restoration. They could surely pay for materials; naturally they would have to agree to the task, and then send you the old designs, drawings and other details. This telescope is a twin of the old one at Pulkova near Leningrad, and the old plans for that one are published and around in very old books.

You would need to respond to indicate your potential interest, first of course without any commitments either way. Then when and if everyone seemed content, you could go ahead.

Write to Professor Owen Gingerich, Harvard College Observatory, 60 Garden St. Cambridge MA 02138. He would share your letter with the others most directly concerned; I am sending him a copy of this note to you.

We are going off to India from Turkey Day to Groundhog Day. I expect to hear more of all this once we are back. Season's greetings!

yours,


Philip Morrison

Over: please file this

Russell W. Elwell
Box 146
Indiantown FL
34956 June 19 1988

Dear Mr. Morrison;

We exchanged letters- one each- in Dec. 1985, largely about
Dr. Derek Price of Yale and the Antikythera Device.

You and your wife do such a good job with the S.A. book review !

I keep on making working models of clocks and instruments. Lately I've
gotten around to power driving an Antikythera. Price and one or two others
have speculated that it was to go onto a statue with a waterwheel drive-
in-as-much as the vessels cargo was statues.

As an easy trial drive I put a $4\frac{1}{2}$ " diam. pulley onto the front center
shaft in place of the $27\frac{1}{3}$ day moon handle.

For drive power, a slow small electric motor is used, with a $1\frac{1}{2}$ " diam.
pulley and a $3/16$ " belt. The big pulley turns once in $3\frac{1}{3}$ seconds-
1081 revs per hour. The old motor is poorly ventilated and gets hot, so
an hour is one batch. So far I've turned the device 6300 revs., or 231
years. So it clearly is possible that this device was set onto a hollow
hand or arm-driven by a water wheel!

My set-up isn't finalised. There is plenty of space in the front area
behind the front plates, for the pulley to go. This front area is where nearly
all the original stuff was lost. The belt could just as easily go downwards
to the power source, where it is hidden.

Driving by the side gear is NO GOOD, mechanically, arithmetically or for
several other reasons. Front center drive, like pushing on your clock's minute
hand, is about 13 to 1 in your favor: Side gear is 1 to 13 against you.

It is a bit more impressive to see all 34 gears turning by this belt
method. I put oil onto things, but it is wrong. the gears tend to spurt
ahead then stop, in a series of hops. Natural friction is best.

This isn't earthshaking news, just a bit of archeological gossip.

(2)

I've a nicely running copy of a Joshua Wilding^{ER}'s 42" tall Grandmothers clock-
been running some 5 months Inside is a wooden works adaption of a Mark
Leavenworth movement. It runs 10 days on one winding (about 23" drop). Very
simple movement;. Eight day wooden movements are all monsters but this is
small and keeps excellent time. But it is tricky to get going in the first
place.

That article about the Italian seaside factory sounds sort of like home to
me as I grew up in the factory-seaport area of Old Cristobal Panama-from
4 to 18 years of age. What became the Yacht Club was a slaughter House when
I was about 10. ~~150 feet from our home~~, . 150 feet from our home, it was a focal
point for buzzard and sharks-not to mention SMELL. I ran, trotted and bicycled,
from 1919 to 1931 around the perimeter of Colon to school-2 miles each way.
Politics was normal which means varying between O.K. and crazy. We survived.

A good writer could list the odds against an Antikythera existing today,
but I can't. The fortunate series would begin with making the original.
Some influential person would have to appreciate it. If normal luck occurred
it would be long-gone by air-corrosion, pillage or melting. But it was sent
toward Rome when some strange chances took place. It sank (and was sort of
kept away from air) .Where it stopped was lucky- not quite too deep to find,
where it stayed for 1900 years. The statue arms showed the treasures and
the device got a ride to Athens. There it was finally seen then studied
with small results. Next luck was \$\$\$\$,Dr. Price and later the X-ray equipment.

Dr. Price and team, plus work, luck and brains resulted in solving the
device.

In my case ,I've no idea why making copies of it came so easily to a
retired mechanic-boilermaker, welder etc. with almost no clockmaking to "help"
me.

I recieved a 1st. prize this Feb. at Orlando's N.A.W.C.C National for
a near-copy of E. Habermels 10" Astrolabe-it is on the jacket of the Nat. Mar.

(3)

It was made several years ago, but I never entered it in competition-
reason being that there wasn't a classification for Metal engraving, until
last year. And a Second prize for a 10" ring Dial plus stand. But I've
yet to see anyone push a Graver at all-Boilermaker's Chipping gun, yes; Graver, no.

All the poor slob's grave cross^{es} in Mt. Hope's cemetery, Cristobal Panama-
interred during the French Canal effort incline me towards ole Fref Allen's
"Life is a Treadmill to Oblivion" idea.

Any~~one~~ who can make something out of these ideas is welcome as I can't.

As a bonus to you... If you can push what is fundamentally Dr. Price's ~~idea~~
work, you are hereby offered one ticket good for one item of my making-your
choice. I'd appreciate part of the material cost. There are ~~se~~ a lot of items to
choose from. *And I enjoy making them. It is cheaper than golf
and my saving multiply a bit in the meantime*

Yours
Russell W. Elwell

Indiantown, FL
Nov. 27

NOV 30 1989

Dear Professor Gingerich;

I wonder if you'd consider an idea I have, a bit?

Two places, locally, have helped me, both are very impressed with your status and their chance to help with your project. So, a short note for each, commending them for their support in a fine public project would be a treasure to them.

I'd guess my delivering each note to them would be best. Their titles are- (1) Stuart Plumbing and Sheet Metal. (2) Indiantown Industrial Supplies. Both names aren't how they really helped. This is a safe thing and not bad publicity, in a way.

The project has reached the stage where ^{PARTS} ~~they~~ are functional. Now the changes to match them to the Base must be done. Weight shells will come from one shop and the help with heavy parts and material from the other.

I'm stuck with a job of making the board etc. for a greatgrandson's Xmas H O train. Trains and rails come from 20 year old stockpile from my sons old hobby shop. Its with his parts and advice. My barn ^{attic} is full of old kits.

Hope you-all have enjoyable Holidays.

Russell W. Elwell

Russell W. Elwell

Box 146

Indiantown FL

34956

Sept. 29 1989

Dear Dr. Gingerich;

OCT 2 1989

The clockwork device is done and runs. An order of small screws ¹⁵ are coming, to complete the case.

It runs on 3 pounds of weight, single line. There are two sets of Fly weights. With the larger ones it goes about $2/3$ as fast as with the smaller ones. And LOW speed is about $2/3$ of what HIGH speed is.

When I wrote and talked to you my thinking was so centered on the Mechanics I wasn't weighing the other details properly; it was foolish of me not to ask you to have the French text translated. Truly, I'd like very much to know what the text really says—two Locals failed and my guesswork is lousy.

As the power output of the Clockwork is so small, the 40 pounds(\pm), less the 'counterweight' must do the actual turning. I wonder how much feedback will speed-up the clockwork? Maybe the small adjuster screws on each Fly arm will do their job.

Would engraving the front and top ^{plates} with Germanic-style border and detail be desireable?

Very truly yours,

Russell Ewell

THUR NOV. 2

I

NOV 6 1989
FRI NOV 10 1989

Dear Dr. GINGERICH:

Just a collection of progress facts as they come to mind.

The Clockwork of course, is done (I've a second one done, onto a wooden base). Yours has brass sides and disc as well as plastic ones.

① the rear upper mounting angle is done. Lower one needs a little paint. Upper one has an added(?) small angle for worm-gear support. All this is running by long cord and goes fine. I've a suspicion that this Worm gear pinion-to-gear is the least good idea in the whole original design and am not approaching the engaging of pinion-to-gear with JOY, at all. Worm gears ~~are~~ are for places where power INPUT must be quite large before you multiply it. This clock is such a power reducer that the output to the pinion is small. ---

② Key is done & lacquered

③ Upper or #1 Arbor details done are: -

① First Cone, done.

② $3/4"$ x 3.7ϕ gear with 104 teeth done. Spacer [H] done. spacer washer done. Spring & its hub, done. The gear (3.3ϕ x $1/2"$ thick, 4 teeth) done. So this # Arbor is done except for shaft - it's on a $1/2"$ ϕ rod, at present

④ Lower or #2 Arbor. All done except that I'm waiting for the brass plate for the largest gear - $1/2"$ x $7 1/2"$ ϕ (\pm) 208 teeth. No problem.

⑤ Inner bearing for \uparrow done

⑨ The weldment (FAKE CASTING) outer bearing etc is done and painted black. Outer "pulleys" etc. done. On this #2 arbor are: Left bearing ^{DONE} ② $\frac{1}{2}$ " steel shaft nearly done. ③ WORM GEAR, $\frac{1}{2}$ " X 4" ϕ with 144 teeth, done. ④ First and second spacers, done ⑤ biggest gear with 208 T. - waiting. ⑥ Long spacer, done. ⑦ outer bearing (g" above) done. ⑧ 2 pulleys and one stud, done.

⑩ ~~The CRANK V-joints, 2 pairs.~~ The V-joint support bracket "h" and "g" on drawing, done & painted

⑪ One of the 2 pair of V-joints done. Waiting for $1\frac{1}{4}$ " ϕ brass bar for second pair. $3\frac{1}{8}$ " ϕ X 6" long short shaft for between V-joints, done.

⑫ The "Engager" ~~to~~ with m and cords 1 and 4 on drawing, are done - except that I'm afraid to join the base piece to the roller-levers part, as it has to fit the BASE and place the Roller properly. It has surplus length or extra and will almost have to be fitted ~~a~~ ON-THE-JOB.

⑬ I wonder if the second one of the gears, shown on the left is missing? Its $\frac{1}{2}$ " thick, $3\frac{1}{4}$ " ϕ with 4 teeth.

Still to do. ① finalize the #1 shaft when the Connector comes from the original. ② Biggest gear no problem ③ What? for main weight pulley cords? I'll temporarily use clothesline $\frac{1}{4}$ " cotton rope ④ Make the 3 weights. ⑤ How much is a LIVRE (Libre or pound in Sp.) ⑥ Pulley for clock weight done - other 2 not yet.


I've made a moderately-accurate wooden Mock-UP of the "SIDE VIEW" of Mainframe or Base, to halfway

III

Check-out how parts fit together - a help to set up running; in clock to #2 shaft, and #2 shaft to #1 shaft - Call it Depting ---

I didn't know telescopes are mounted at 90° minus Lat. The fact never came my way.

And it took me a month to notice Centennial Year and Sesquicentennial. 1200 c.c. of brain aren't enough sometimes. But I keep my fingers out of the 5000 RPM Fly Cutter - so far anyway.

It is odd that you can buy Gold, Silver, Alum. and steel easily enough. But BRASS - - trouble. Especially sheet brass. Small shops? Never. Big shops? Rarely. Campbell Tools in Springfield Ohio is the best source I've found. Brass was hopeless for the top piece of the clock  - it took a 3 county search to get "IRON" and then 80%+ ~~turned~~ became scrap turnings.

The little book I've got is "Early Science at Harvard" and I see "15 inch refractor" on page 60 - Gee - even to Indiantown - word gets around.

This seems to be a fairly close summary and if some error is apparent to you, let me know

Russell Elwell



Harvard-Smithsonian Center for Astrophysics

60 Garden Street, Cambridge, MA 02138

(617) 495-7000
Telex # 921428



A208 or Mail Stop 9

GINGER@CFA or CFA::GINGER

(617) 495-7216

September 29, 1989

Mr. Russell W. Elwell
P.O. Box 146
Indiantown, Florida 34956

Dear Mr. Elwell:

Those of us concerned with the restoration of the 15" refractor (including our Director, Irwin Shapiro) were delighted to hear about your progress in replicating the original clock drive. The delay in reply came about because I waited to have the enclosed photographs for you. The scale on the pictures is in centimeters. The photographs show various modern attachments, which will all be stripped away in order to accommodate your clock. I have not yet counted the teeth on the main gear wheel, but I shall send that shortly.

It seems to me that it might be nice to have two cover plates for the mechanism, one in brass and the other in plexiglass. I think we would normally use the plexiglass cover so that visitors could admire the clock work. We have just received a \$12,000 grant from the Smithsonian Institution for planning the exhibition areas within the tower that houses the telescope. I am very excited about the prospects of making the area fit to be seen once again.

Sincerely yours,

Owen Gingerich
Professor of Astronomy
and the History of Science

OG/jj
Enclosures

HARVARD COLLEGE OBSERVATORY
Sesquicentennial Year 1989

SMITHSONIAN ASTROPHYSICAL OBSERVATORY
Centennial Year 1990

Sept. 4th. 1989

SEP 11 1989

Dear Prof. Gingerich;

The governor-box is running. The brass cover plates are on the bottom, two sides and top. The disc on the Fly space is still of plastic, to see through.

It looks very attractive. Last Tuesday I showed it at the local Astronomy Club meeting. The early ideas fascinated them, especially the 40 Lbs(?) weight. Also at our Chapter 99 clock meeting, the strange clock gearing, the clearly early design (plus Harvard) sure caught their attention. I gave a short talk.

'Grave par A. Moyseff' -- He was good, and careful. The 'doubler' inside the front plate is the guide for the moving Runners that control the speed.

LOWERED WEIGHTS
GIVES 7/RPM

Using FULL-Sized Governor Fly weights the maximum speed, with 3# weight, is 10 R/M. of the output shaft that will have the ~~Small~~ Worm pinion on it. The other extreme is a Fly arm with NO weights on it -- then it does ~~FLY~~!! 115 R/M. So a wide choice is available.

I'd like to know if the largest gear (call it #1) is still on hand and how many teeth it has -- to get what speed is needed at the governor ~~gear~~ shaft. If it is there, I'd like the arc shape, the tooth shape and the tooth count.

Measuring carefully, times 4, ...,

^{BIG WORM}
#1 gear is 15.88" Diam. Next one, #2 is 3.88" diam. Next, #3 is 7.48" diam. ^{BIG WEIGHT SHAFT}
Worms seem to be drawn about .93" diam. #4 is 5.3" diam. -- call it small Worm.

If so, Big Worm is 3 times the size of Little Worm and #2 & #3 are ~~to~~ to a 1.92 ratio -- (2)7

It would be handy if #1 has a tooth count of 360 (15 teeth for an hour's turning) or 432 teeth (for 18 t/H) BEST.

With those diameters the tooth count could be

#1- 15.88 D has 432 T (at my .115" each tooth & gap) Problem here if it's 360T.

#2- 3.88" D. has 106 teeth.

#3- 7.48" D. has 204 teeth

#4- is 1/3 of #1 or 144 teeth.

Each Worm pinion revolution gives one ~~rev~~ tooth of its gear. If it is 432 teeth on #1, first worm and its shaft turn 18 times an hour and so does gear #2 (same shaft). This #2 turns 1.92 times as fast as #3 -- 18 revs X 1/1.92 is (over)

(2) (abt.)

9 3/8 Revs/^{HR} min. So does #4 (same shaft). If #4 has 144 teeth, it is 144 X 9 3/8 or 1350 Revs of governor shaft, per hour. This is 22.5 R/M. If #1 is 360 teeth it is 2/3 of this. So, my present fly weights are too heavy---No problem.

I think I've thought of a method of making the worm gear on my equipment. And probably the worm pinion too.

My wife insists that I make a second one to show, as it is such an attractive object. So I've the second gears and other parts made too. But there are a lot of things to decide yet on the first one, supports, brackets....are any of them on hand? THERE MUST BE SOME SORT OF SUPPORT FOR THE GOV. OUTPUT - PINION SHAFT, UNDER GEAR #4. I'VE LEFT THIS SHAFT EXTRA LONG. THERE MAY BE DETAILS THAT I'VE OVERLOOKED ENTIRELY. IF YOU CAN THINK OF TRAPS, SHORTCUTS FANCY DETAILS --- ? PLEASE TELL ME. IF YOU THINK OF CHANGES, ADD-ONS --- ? IT SEEMS TO BE GOING WELL SO FAR.

Was it Steven Kramer III Russell Elwell
who worked on D. Rittenhouse's
Orary at Princeton? He did
a lot of work with Stacey Woods
on and about Pennsylvania
clocks.

Aug. 4, 1989

AUG 10 1989

Dear Prof. Gingerich;

The information came about the 21st of July and I was very pleased to see it. I'm delighted with such an interesting instrument. The clockwork is going quite well.

First thing was to Xerox the sheets and see a friend. She went to French school at Newport Vermont, years ago. We 'muddled thru' it a bit-she with the French and me with the clock jargon. We got the trend and a bare veneer.

It seems that the largest weight 'e' on the endless cord gives most of the power- the clock sort of 'governs' the speed...? That happens when the worm on the shaft of the Crown wheel turns, or lets turn, the large wheel it meshes with.

But the tooth counts are difficult. The power would turn the 'scope at 15° an hour, max. Often less than this would be preferred?

So, or anyway, I've got a guesswork or prototype fairly well along. First was a Times-Four drawing. The tooth count was picked by the gear diameter, with Module #1 teeth. If this one is too fast or slow, the next one will be within range. 4 pillars, done. Great wheel and Drum assembly, done. #2 gear and Crown wheel, done. The 2 pinions, done. Puzzle- the artist A. Moyséeff, seems to have a spare arbor, empty; see it above the Great Wheel and below the Pinion? Usually these early Foliot's have only 3 arbors. These parts will be put to running to see what the high and low speeds are.

Probably when you get back from your trip this first one will be running. Maybe it would be easier to telephone? We are 'out' only about a day a month. The Area # is 407---597-2988.

This project is so fascinating, you can rely on me; and often I'm lucky.

Thank You,

(But not necessarily with tapping)
Russell Elwell

Felberich

SHAPIRO
4170 PINOCT
BOULDER CO 80303

SEP 28 1989
8:37 PM

Owen -

Reur inquiry, The rotating desk
is 8 feet in diameter. The center post
is about 8'3" high. We have an
extension of about 12" to reach our
ceiling. (The rotating, independently,
center bookcase is 4' in diameter).
FYI, the desk proper breaks down
into 2 pieces. The bookcase doesn't.
The support comes apart like a Tinker Toy.
The desk working space is 29 3/4 inches
above the floor. There are 12 drawers.
There are 12 sections in the bookcase, half
rectilinear, half wedge-sh-bd; 26" overall
inside height 13" bottom shelf, 11" upper shelf. OK?

Alan Shapiro



OCT 10 1989

Prof Owen Gingerich

A208/Harvard-Smithsonian Center for
Astrophysics

60 Garden St

Cambridge, Mass 02138

POP-VERLAG HEIDELBERG - FOTO FRIEDEMANN POPP

FF 2608

Harvard University/Atmospheric Research Project



Engineering Sciences Laboratory
40 Oxford Street, Cambridge, MA 02138

617-495-5922

NOV 5 1990

MEMORANDUM

TO: Distribution
FROM: Nate Hazen
DATE: October 31, 1990
SUBJECT: Replica Merz & Mahler drive for the 15" telescope.

This is to notify all concerned that I have now received all the parts of the replica Merz & Mahler governor drive that was commissioned by Owen about a year ago.

The drive replica was made by Russell Elwell (PO Box 146, Indiantown, FL 34956), an amateur clock and instrument maker, principally from the engraved plate illustrations of the Pulkova 15". The plates are from 1839 and show the device from an illustrator's point of view. Nonetheless, they are quite highly detailed and with some interpretation (and Mr. Elwell's skill) have yielded a beautiful display replica.

The Harvard telescope is at a different latitude, of course, so a few modest alterations had to be made to the configuration. To support this I made a dimensional survey of the relevant areas of our 15" about a year ago, detailing the exact location of the mounting holes and their relationship to the drive worm and worm wheel. These relationships have been incorporated into the replica. The same survey indicated, however, that significant alterations had been made to the worm shaft and its environs in the 1955 "refurbishment". These will have to be corrected before the replica drive could be connected in any way. In fact Mr. Elwell, at my request, has left the final output shaft and certain other parts of the replica unfinished so as to facilitate the corrections.

Mr. Elwell actually ran the assembled drive for a while and ascertained that the output rate was about what was required by the worm on the RA axis on the 15". He also observed performance difficulties which must be similar to those reported by Bond in those first years after 1846, namely that the governed rate was unduly sensitive to variations in the driven load. As we know, this gave rise to the replacement of the M & M drive with one made by the Alvan Clark firm in 1856.

I've had occasion recently to spend some time at the University Photographic Archives and have sorted thru a lot of old Observatory material to find what few pictures they have of the 15" telescope. There are the 3 or 4 familiar representations we have all seen of the 15" with the Clark drive at different times and from different angles, but I came up with one striking

photo showing an early version of that drive, seemingly with pendulum/escapement regulation, and with the M & M drive still in place (presumably disconnected) behind it. In all later photos of the Clark drive it is alone and fitted with additional bracketry and a fly-ball governor. These photos are now being copied at the Fogg, along with an enlargement of the drive area described above.

It is my plan to put Mr. Elwell's replica together on the work stand he made so that it can be shown to those interested. What with other things going on, this may not be done for several weeks; meanwhile, the parts may be seen in my office at ESL, 40 Oxford.

Mr. Elwell has spent a considerable number of hours on this replica over the last 6 months of 1989 and into 1990. I understand that he is not expecting (nor does he seem to want) compensation for his time. He has clearly also invested a significant amount in materials for the construction, and incurred a \$75. postage cost in getting them to us. I'm sure the Observatory can come up with a suitable letter or letters of commendation and perhaps a quality gift-in-kind (books from the Observatory, or the Historical Instrument Collection?) in due course. Let me know if I can help.

Distribution:

Owen Gingerich ✓
Fred Seward
Irwin Shapiro
Will Andrewes
Peggy Herlihy

Harvard University/Atmospheric Research Project



Engineering Sciences Laboratory
40 Oxford Street, Cambridge, MA 02138

617-495-5922

REC'D. NOV 5 1990

DIRECTOR'S OFFICE

MEMORANDUM

TO: Distribution
FROM: Nate Hazen
DATE: October 31, 1990
SUBJECT: Replica Merz & Mahler drive for the 15" telescope.

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The Harvard telescope is at a different latitude, of course, so a few modest alterations had to be made to the configuration. To support this I made a dimensional survey of the relevant areas of our 15" about a year ago, detailing the exact location of the mounting holes and their relationship to the drive worm and worm wheel. These relationships have been incorporated into the replica. The same survey indicated, however, that significant alterations had been made to the worm shaft and its environs in the 1955 "refurbishment". These will have to be corrected before the replica drive could be connected in any way. In fact Mr. Elwell, at my request, has left the final output shaft and certain other parts of the replica unfinished so as to facilitate the corrections.

Mr. Elwell actually ran the assembled drive for a while and ascertained that the output rate was about what was required by the worm on the RA axis on the 15". He also observed performance difficulties which must be similar to those reported by Bond in those first years after 1846, namely that the governed rate was unduly sensitive to variations in the driven load. As we know, this gave rise to the replacement of the M & M drive with one made by the Alvan Clark firm in 1856.

I've had occasion recently to spend some time at the University Photographic Archives and have sorted thru a lot of old Observatory material to find what few pictures they have of the 15" telescope. There are the 3 or 4 familiar representations we have all seen of the 15" with the Clark drive at different times and from different angles, but I came up with one striking

Cy ID: Owen Gingerich

Owen: Please draft
a letter of ~~thanks~~
thanks and a
suggestion for a
suitable gift.

Thanks!

Im

11/05/90

photo showing an early version of that drive, seemingly with pendulum/escapement regulation, and with the M & M drive still in place (presumably disconnected) behind it. In all later photos of the Clark drive it is alone and fitted with additional bracketry and a fly-ball governor. These photos are now being copied at the Fogg, along with an enlargement of the drive area described above.

It is my plan to put Mr. Elwell's replica together on the work stand he made so that it can be shown to those interested. What with other things going on, this may not be done for several weeks; meanwhile, the parts may be seen in my office at ESL, 40 Oxford.

Mr. Elwell has spent a considerable number of hours on this replica over the last 6 months of 1989 and into 1990. I understand that he is not expecting (nor does he seem to want) compensation for his time. He has clearly also invested a significant amount in materials for the construction, and incurred a \$75. postage cost in getting them to us. I'm sure the Observatory can come up with a suitable letter or letters of commendation and perhaps a quality gift-in-kind (books from the Observatory, or the Historical Instrument Collection?) in due course. Let me know if I can help.

Distribution:

Owen Gingerich
Fred Seward
Irwin Shapiro ✓
Will Andrewes
Peggy Herlihy

15" Restoration
Elwell clock

Russell Elwell
15600 Palomino Rd
Indian Town, FL

for UPS

Elwell, R.

Less tidy thoughts

Indiantown

Jan. 3, 1991

The Space-Travel books in my early days, regrettably, were fiction. R.R. Burrows Mars & Venus; Dear Owen;

JAN 7 1991

and Pelucidae. Our diet was dried Cod & fish, mackerel, and dried or canned beans. I thank you very much for the books. Very interesting- they are what I learn from. I've gone through the HCO-the First four Dir. rapidly (slow, later) and the smaller HCO & SAO studiously. When I've finished David Landes' book, I'll write him a letter via you.

Then the surprise in Dec's. "Smithsonian"-last article. All the years of Langley-panning and I'd never read the real facts about him. I saw the Navy converted collier Aircraft carrier several times in Colon harbor-should have suspected he did a lot or he'd never have held that important job.

The Great Refractor is the large dome to Director Shapiro's left, I'd guess-partly from Nate Hazen's photo of the inside.

I remember Smithsonian's station on Gatun Lake, Barro Colorado.

The photo of "Field Station", page 133, seems new to me. Toggle light switches and construction details. I lived in a Panama French-made house of 1880, in 1919-my age was 6. It had tongue and groove wall boards; the exposed wiring was the yellow and green braided cord onto white porcelain insulators and push button switches. The light shades were the same, none. No flies but lots of cockroaches-they got there first-always hungry....

Science fiction is pale, sorry stuff compared to what you all work, delve, search think in. Fascinating.

Again, I thank you for the books. If there is anything to help you all, ^{with} let me know. It is fun to make antique scientific inst., Marine nav. stuff, quadrants, nocturnals, astrolabes....

Russell W. Elwell

Less tidy thoughts--

The Space-Travel books in my early days, naturally, were fiction. E.R. Burrows Mars ^{GHS} and Pelucidar⁴. Our diet was dried Cod Fish- bacal^{AO}ew- and dried or canned beans. So, of course, we assumed John Cart^{er} got to Mars via jet propulsion. It was to be hoped he was able to distinguish between flatulence and Montesuma's Revenge.

The wall of my father's Custom Office had a hundred slots for name stickers to stick onto suitcases. So our bags had lots of odd (but untrue) names glued onto them- Iquitos, Baranquilla, Cochabamba, Callao, ^(B E L E M) Pernambuco, Rio, perhaps Arrequipa ?/

As the American schools were excellent, rich Panamanian kids were in our classes, along with kids of Rear and Front Admirals, Sergeants, rich Englishmen and, ugh, workmen. Very clever kids, snobs, talented, you name it. But usually there was a twist or avenue to use so things settled down (Emerson's Compensation ?) I then had a very good ability to memorise.

It is doubtful if I'll go to Clock Club meetings anymore. ^{78 years OLD} 40 miles each way or further. My wife never did enjoy them. Conditions change. The one man I liked best has died. Elmer^B Giles made 5 million-plumbing-had a big shop with 2 Or 3 clock repairmen. He's the only one I took my clock problems to. Neither of us had to be fakers but could smell one and enjoyed their skill at it.

Oh well, things are fine with us and the family numbers 14 by now. No complaints.

R.W.E.

Elwell

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GINGER@CFA or CFA::GINGER

(617) 495-7216

17 December 1990

DRAFT

Mr. Russell W. Elwell
P.O. Box 146
Indiantown, Florida

Dear Mr. Elwell:

Your ingenious and dedicated craftsmanship has given the restoration project of our Great Refractor a very welcome impetus. In the not too distant future the replica clock drive that you have made will be installed on the telescope, and eventually it will be admired by the hundreds of visitors who come to our monthly Open Night Programs. We are immensely grateful to you for your immense and painstaking effort, not to mention the fact that you have also contributed all of the materials as a gift to us.

As a token of our appreciation, we are sending under separate cover three books that we hope that may be of interest to you. David Landes, Professor of History and Economics at Harvard, has autographed a copy of his *Revolution in Time*. All of the astronomy faculty have signed a copy of Bessie Jones and Lyle Boyd's *The Harvard College Observatory 1839-1919*, and Owen Gingerich, who is playing a major role in the restoration project, has signed a copy of the recent anniversaries volume that he edited. We hope you will enjoy these books as a symbol of our appreciation.

We hope eventually to send you photographs of the instrument when the restoration has been completed and the clock drive installed. We hope that you will be able to come to visit your handicraft when it has been installed.

Sincerely yours,

Irwin Shapiro
Director

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Elwell

18 December 1990

DEC 20 1990

Mr. Russell W. Elwell
P.O. Box 146
Indiantown, Florida

Dear Mr. Elwell:

Your ingenious and dedicated craftsmanship has given the restoration project of our Great Refractor a very welcome impetus. In the not too distant future the replica clock drive that you have made will be installed on the telescope, and eventually it will be admired by the hundreds of visitors who come to our monthly Open Night Programs. We are immensely grateful to you for your considerable and painstaking effort, not to mention the fact that you have also contributed all of the materials as a gift to us.

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We hope eventually to send you photographs of the instrument when the restoration has been completed and the clock drive is in place. We hope that you will be able to come to visit your handicraft when it has been installed.

Sincerely yours,

Irwin Shapiro
Director

copy
IS/OG/jj

HARVARD COLLEGE OBSERVATORY
Sesquicentennial Year 1989

SMITHSONIAN ASTROPHYSICAL OBSERVATORY
Centennial Year 1990



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19 November 1990

Mr. Russell W. Elwell
P.O. Box 146
Indiantown, FL 34956


Dear Mr. Elwell:

Thanks so much for your letter and even more for the clock drive, which is here and has been running in Nate Hazen's office. We will inform you promptly when it is actually installed on the renovated telescope.

We have in mind to send you a little gift of appreciation for your work. It will be a group of three books, but we are collecting some autographs in them before we send them, so it will still be a few days before they are sent.

The fossil hunting Peter Gingerich is unknown to me, but possibly a relative as there aren't all that many who spell it this way. (The representative from Georgia spells it Gingrich, and I claim no relationship!) There is an anthropologist Philip Gingerich whom I have never met, but his name comes up from time to time in scientific circles.

Sincerely yours,


Owen Gingerich
Professor of Astronomy and the
History of Science

OG/jj

HARVARD COLLEGE OBSERVATORY
Sesquicentennial Year 1989

SMITHSONIAN ASTROPHYSICAL OBSERVATORY
Centennial Year 1990

Nov. 5 19 90

NOV 8 1990

Dear Owen;

Nathan Hazen ~~wrote~~ ^{phoned} and said the five packages arrived in good shape. A relief, as I'd hate for any of them to have been lost.

I thank you very much for the opportunity of working on the job. The cost to me was about \$100 which is small considering the fun-golf would have cost many times that.

When the data came from you and I saw the size of those three big gears, my knowledge of "How to Do" was zero. But John Wildings' book about 'Crystal Wheeled Skeleton' came. It casually lead into Module #1 gear teeth. They're monsters, 1/8" from tooth tip to Tooth tip. Perfect information. A little scary at first.

My routine for gear-cutting is totally free of crap. A small Sears attachment holds a 1/15th. H.F. motor (Dayton # ~~10~~ ^{\$30 now} 2MC57). Motor turns my Fly-cutter at 5000 RPM. That's it. Pratt & Whitney, for example, would have used \$1500 worth of gear cutters for the job.

I read in Smithsonian, Tech. Rev. or Sci. Am. where a Peter Gingerich was described while hunting in Wyoming, for fossils. I was in Wyoming once, for a week in 1928, which is a small hunk of time back toward fossils. Then we went South to Salt Lake City. At

old Salt Lake (park) I expected to float almost atop the water but it wasn't much more buoyant than the ocean to me.

I saw your recommendation in DOVER... and sent off for H.B. King's History of Telescopes. I've his 'Geared to the Stars.' -copied the water-wheel of the Chinese device for Dr. Price to show at a lecture. It has the escapement device.

DOVER had a book 'Aviation History on Long Island'. I worked at Howard Aylord's place Waco Sales & Service at Roosevelt Field - shown in photo 272 and at North Beach Airport photo 263. This was in 1934. I knew maybe 2/3 of the people and planes shown. The Army Airforce was wide-open to us kids in Panama, ~~1920~~ 1920 to 1931. There aren't many of us Gringos with a machete scar.

The piece in Tech. Review was surprising (James Cornell ^{is}) to me. I'd no idea that amateurs were so useful and put to work in Astronomy. Also it was relieving (?) to me, because Amateur includes me. The only one I compete with is me (I)?

Like the Stargazing amateurs, I'm thankful you picked me for your 'scope device. If there's anything you can think of in the future please remember me.

Russell W. Elwell



Harvard-Smithsonian Center for Astrophysics

60 Garden Street, Cambridge, MA 02138

A208 or Mail Stop 9

GINGER@CFA5 or CFA5::GINGER

(617) 495-7000

Telex # 921428

(617) 495-7216



April 25, 1990

Mr. Russell W. Elwell
P.O. Box 146
Indiantown, Florida 34956

Dear Mr. Elwell:

It is nice to hear from you again. I have had steady reports on your progress from Nate Hazen. I assume that he has given the information you need about the interface.

Dr. Jurgen Teichman is still curator at the Deutsches Museum in Munich. They have on exhibit the Fraunhofer telescope used by Bessel that is the forerunner for ours here.

I assume that "Livre" is close enough to a pound for everything to work. Do I still owe you a translation of a section of the Pulkova French?

Sincerely yours,

Owen Gingerich
Professor of Astronomy
and the History of Science

OG/jj

Dear Prof. Gingerich;

APR 29 1990

Elwell
April 20, 1990

My granddaughter was here last Sunday-brought two Annual Reports from her job with Siemens in Boca Raton. I noticed they have a large office in Munich, so I brought in the Deutsches Museum catalogue (6), assuming that the Museum and Siemens would be frequent co-workers.

For all I'd thought I'd read the catalogue carefully I'd missed a lot. The drawings ABB123 (20 cm scope) 30 degree mount-ABB185 (1824)-ABB186 Russian Observatory (1839-45)-Abb240 (1846): All had the same type of Drive.

Dr. Jurgen Trichman curator-1980-sent me the catalogue (#6) and a smaller one. This was after Dr. Price had arranged the delivery of an Antikythera Device to Munich.

I'll get Gerhard Hutter to do a 'quickie' translation of the above subtitles next Clock meeting. He'll owe me- I'm making him a copy of the German Dial shown on the jacket of Nigel Hawkes' Early Sci. Inst.

My suspicions of the Worm- worm wheel contact point must be wrong, because it worked in the above 'scopes. Both the 'clock' and the set of gears turn very easily on my stuff. The German way must be O.K. if the two weights are correctly arranged ...? Neither the worm or the worm gear exactly drive each other.

The weight cases are overly large so there's room to add more segments of lead into each case. I assume a LIVRE is a pound? My weight cables aren't good- perhaps they used animal sinew belts then?

I'll show the 'scope drive assembly at the next Clock meeting together with drawings, letters and the Munich catalogue.

Oh, my granddaughter likes her Siemens job. Like most of the employees, she's going to Night School, at their encouragement-splendid Company. An early Cessna at Newark Air Service, 1934, had a radial Sieman-Halske engine.

Sincerely yours,

Russell W. Elwell

Harvard University/Atmospheric Research Project



Engineering Sciences Laboratory
40 Oxford Street, Cambridge, MA 02138
617-495-5922

CC;
Alan Gingrich
DEC 7 1989

December 4, 1989

Mr. Russell W. Elwell
P.O. Box 146
Indiantown, FL 34956

Dear Mr. Elwell,

Enclosed at long last is the diagram I promised you - a full scale layout of the East side of the mounting bed for the Harvard 15 inch telescope. The emphasis is on the mounting holes for the Merz & Mahler governor/drive and the shaft end for the worm of the right ascension drive. A few other things are shown, but some are not, so you should also be guided by the photograph which you have of that side. (The small electrical box and the right angle bracket for the modern drive shaft have been permanently removed, however. They had been fastened at the "recent" holes indicated as R1 thru R6 on the plan - some rather ugly 1/4 - 20 tapped holes which may be plugged during the restoration.)

The coordinates for the holes are from the origin indicated; the accuracy is probably within + or - 0.010 inches. In those cases where an inter-hole distance is useful I've measured and indicated it. The nature of the holes is as follows: (I haven't yet determined the exact diameter and pitch for the threaded holes, though).

Hole Designation ~~~~~	Quan. ~~~~~	Major Dia. ~~~~~	Pitch ~~~~~
A1-A6, Threaded holes	6	approx .390"	TBD (fine)
Companion pin holes	5	approx .115"	
B1-B2, Threaded holes	2	approx .285"	TBD (fine)
C1-C2, Threaded holes	2	approx .350"	TBD (fine)

Note that the holes "B" and "C" are lined up with the horizon.

There are some other apparently original holes on other faces of the mounting bed which I have not indicated. In particular, a screw hole with companion pin hole is on the top face (note the screw head illustrated near the worm shaft in the Pulkova Fig. 2), and there are several more on the West face. I have also not shown the large-headed mounting and adjusting screws associated with mating the mount bed to the granite pier; these are clearly shown in the photo and are well clear of the clockworks area.


The worm shaft end is as I have dimensioned. I would guess this was done (i.e. the shaft sawn and turned) in 1955 - a darn shame, because to properly adapt to your gear and clutch the whole end of the shaft will have to be restored. This should be the subject of more discussion before you put too much effort

into an adaption. Note that the shaft passes through a pivoting journal block at the East end, just at your "first cone". The shaft is spring-loaded toward the center at the other (West) end to keep it in firm contact with the worm gear, eliminating lost motion. There was also a spacer/thrust washer where shown. The "modern" reconstruction used this and a set-screw secured coupling hub to set end play of the worm shaft - a critical factor in drive precision, and not well done. I suspect the original used the clutch spring to preload the whole stack and keep the end play to zero.

As I passed on to you by phone, but to repeat for reference, I measured the worm / worm gear ratio and found it took 24 turns of the worm to advance the RA gear one sidereal hour, or 15 degrees. Your works should then have an "arbor #1" output of about that at mid-range, or one revolution every 2 1/2 minutes.

Please feel free to give me a call as any questions come up. It's relatively easy to dash up and make a measurement or two. My phone is (617)495-5922.

Sincerely,

A handwritten signature in dark ink, appearing to read "Nate Hazen", with a long horizontal flourish extending to the right.

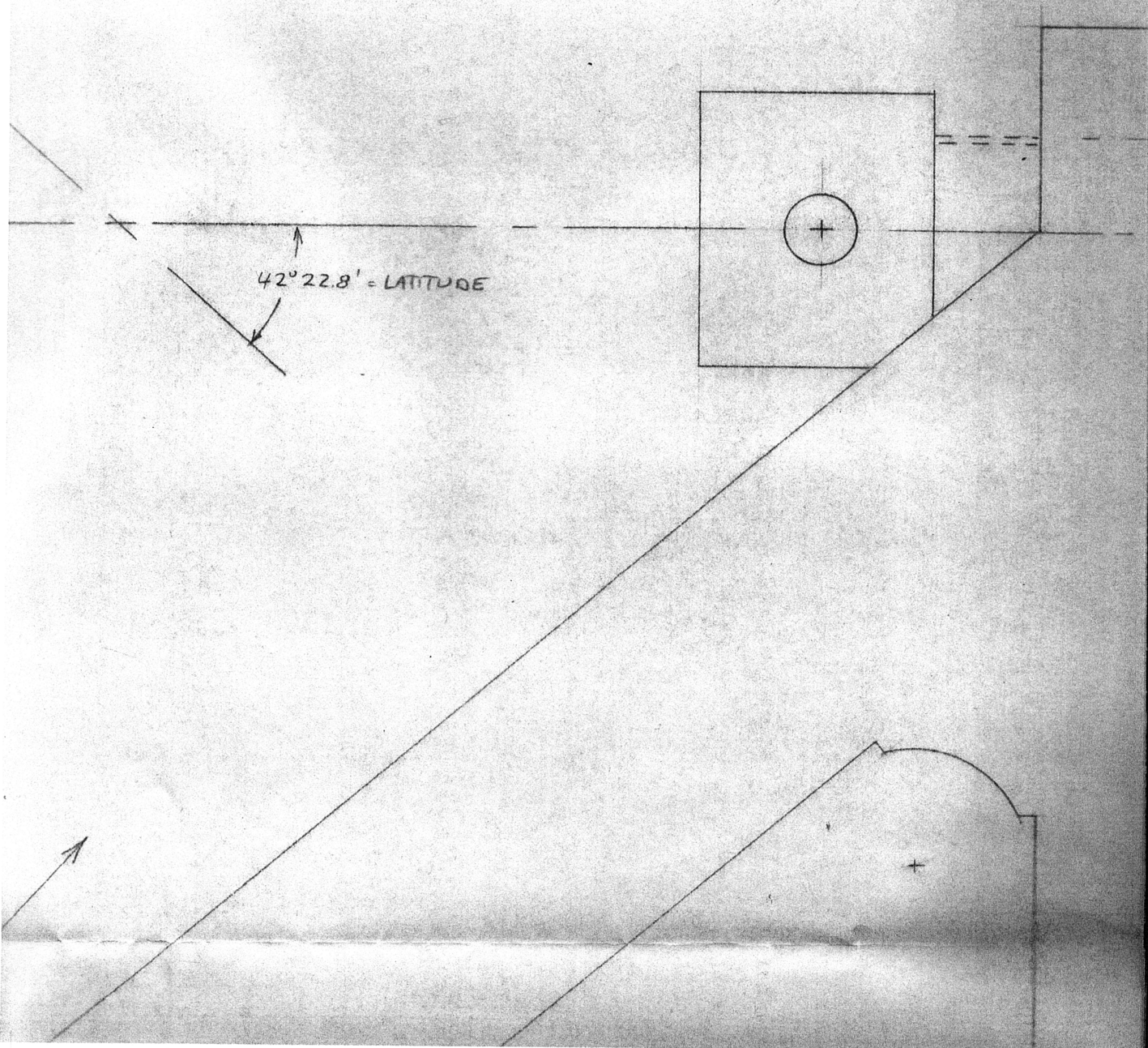
Nathan L. Hazen

HOLE PATTERNS - HCO 15" TELL

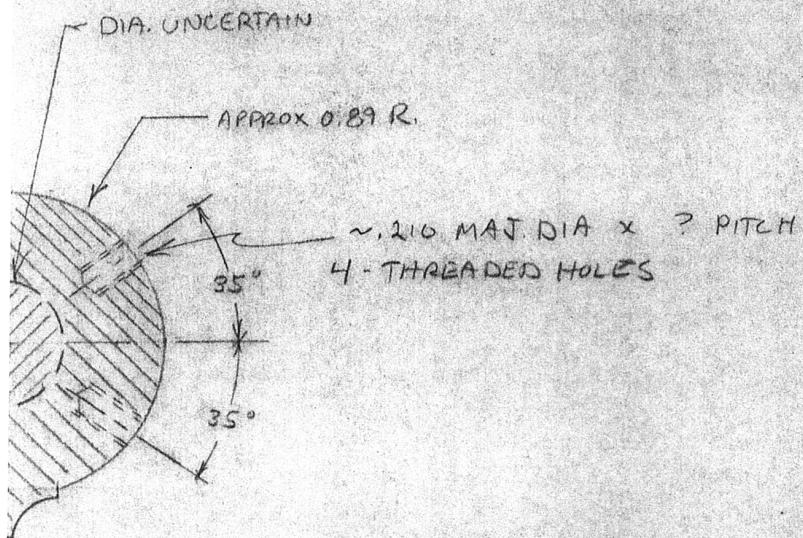
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NLH

PARALLEL

PIPE - EAST FACE

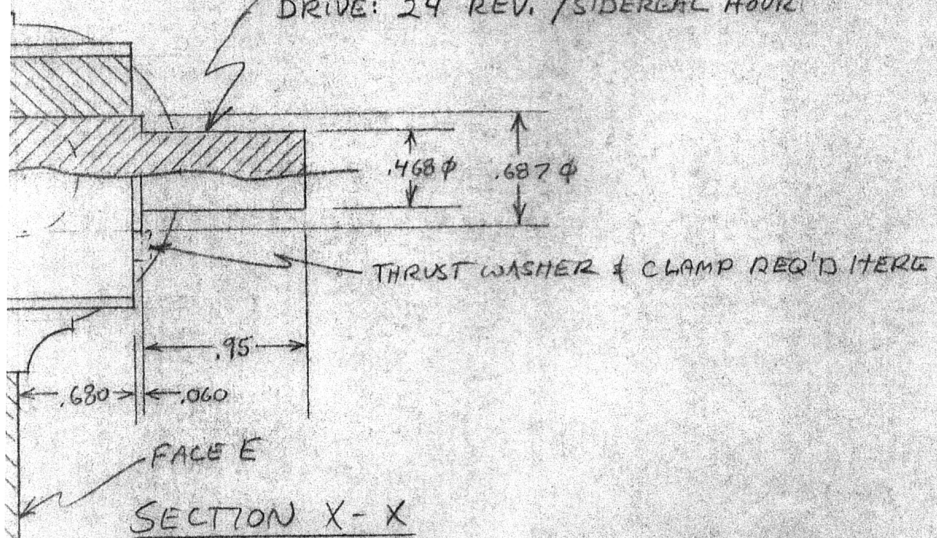


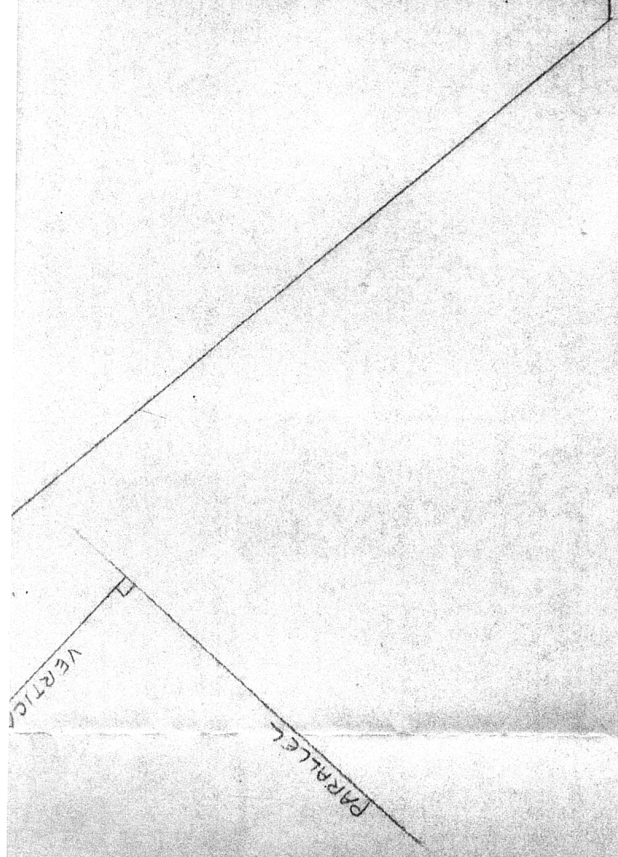
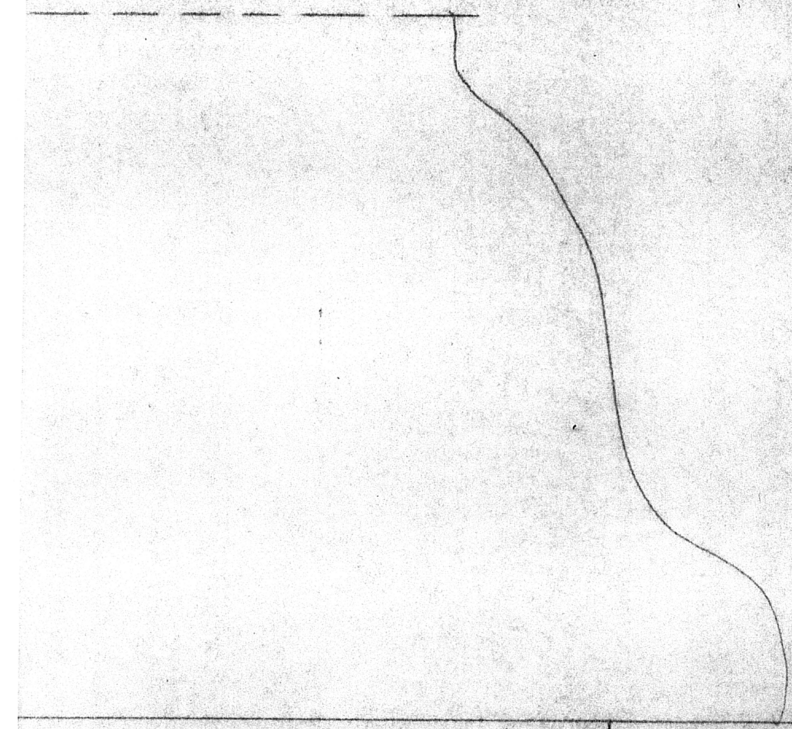
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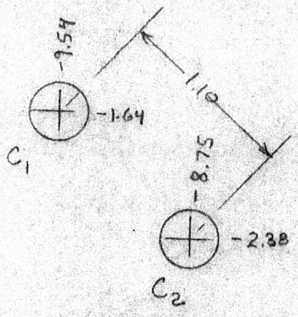
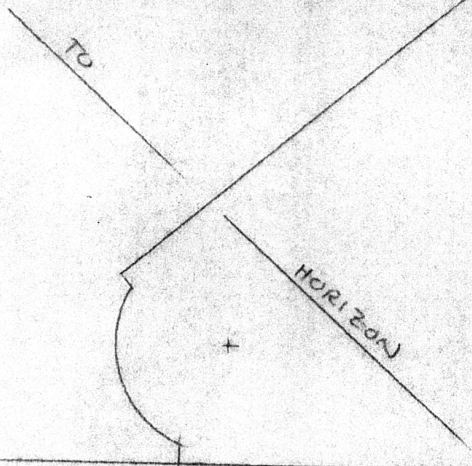


SECTION Y-Y

WORM SHAFT:
DRIVE: 24 REV. / SIDEREAL HOUR



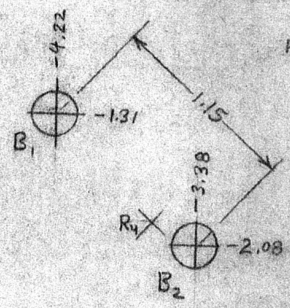




R_1

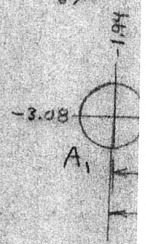
R_2

R_3



R_5

R_6

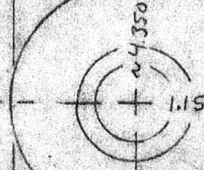
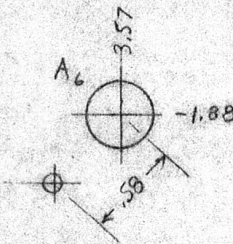
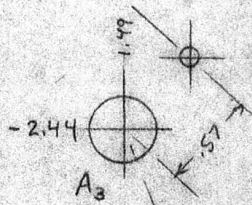
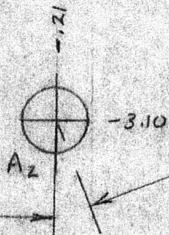
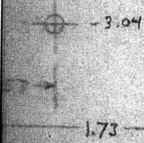
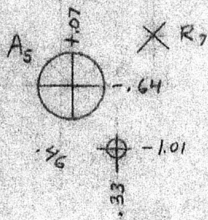
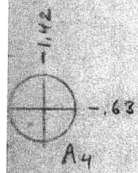


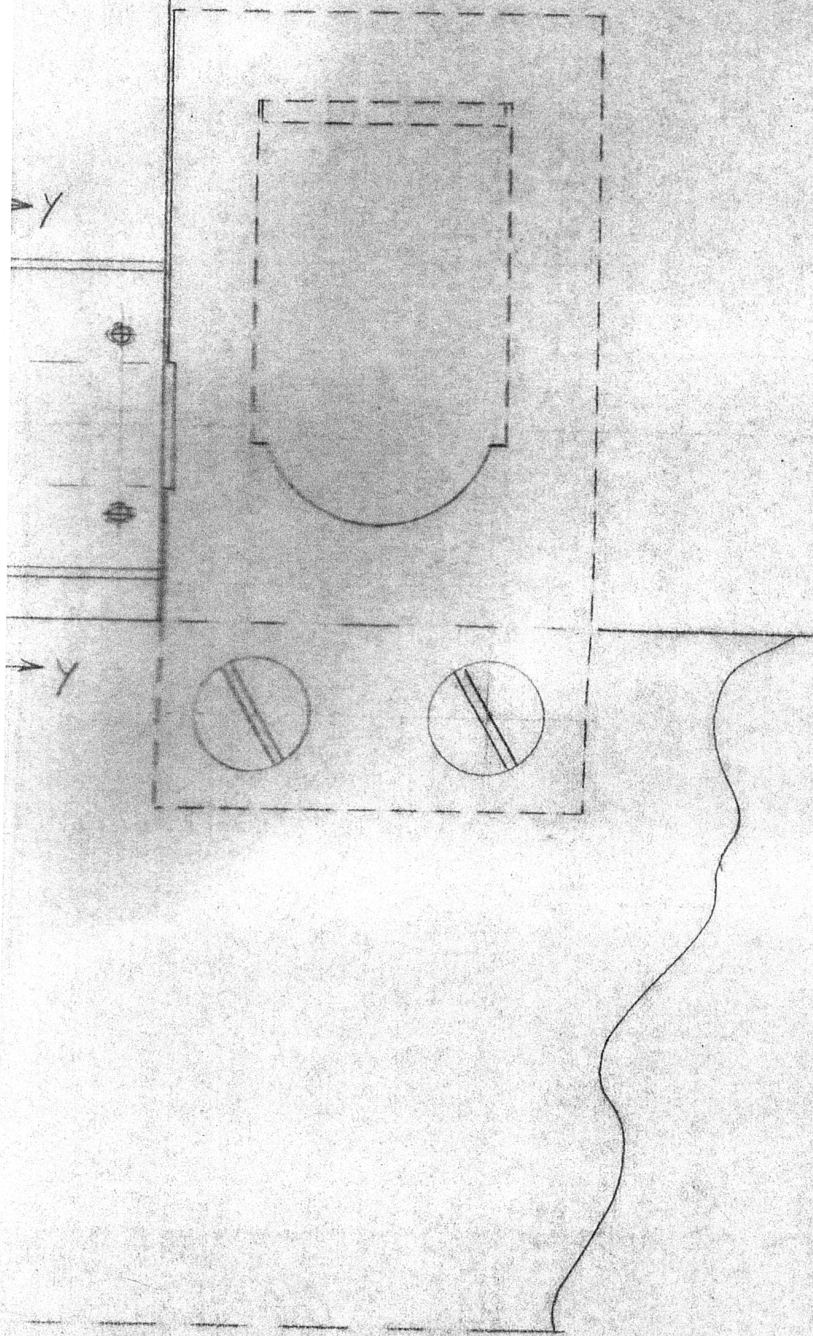
RA WORM GEAR
& HOUR CIRCLE

ORIGIN OF
COORDINATES

OLD HOLES IN TOP FACE

FACE E



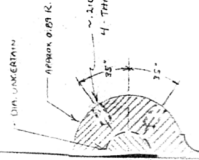
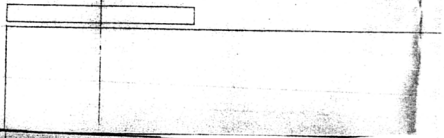
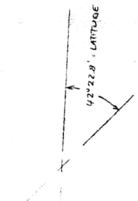


PHITRENS - HCO 15" TEL

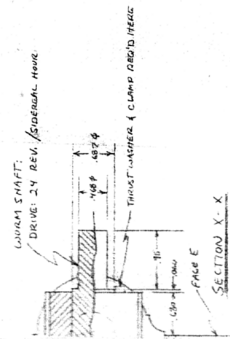
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1:10 - EAST FACE

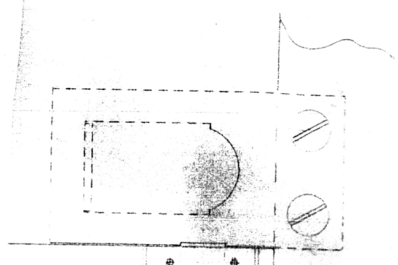
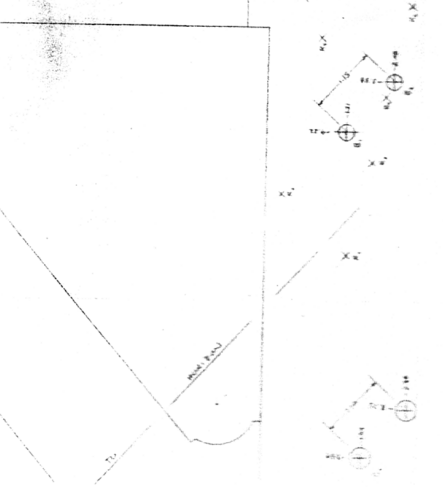
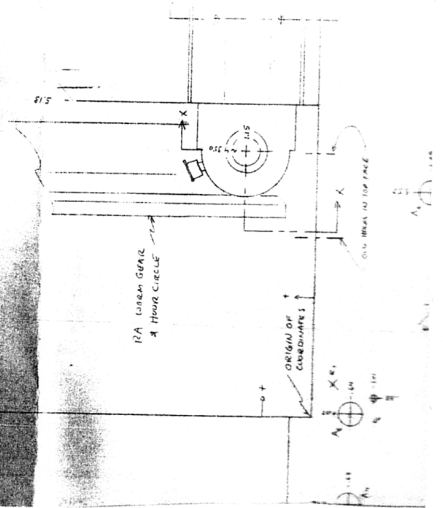
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JCM 2016



SECTION X-Y



SECTION X-X



Elwell



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(617) 495-7000

Telex # 921428
(617) 495-7216



July 20, 1989

Mr. Russell W. Elwell
P.O. Box 146
Indiantown, Florida 34956

Dear Mr. Elwell:

The spring semester moved so swiftly that I lost sight of the project in which we are hoping for your wonderful assistance and collaboration. Please accept my apologies for being so remiss.

I am taking this opportunity to send you the complete set of existing information about the clock drive. There is a plate reduced to exactly 1/4 of the full size (in two pieces) and a detail of the very large plate showing the telescope. I am enclosing the French description of the clock. We will be happy to supply a French translation if that would be useful to you.

As far as I know, the original worm gear and worm are still in place, but in the coming weeks I will supply a certain number of photographs so that you can see exactly how much of the original mechanism still remains.

I look forward to your comments about the feasibility of the project based on this relatively sparse amount of information. I am going to be overseas between July 27 and August 15, so I won't be able to respond to you during that interval.

Sincerely yours,

Owen Gingerich
Professor of Astronomy
and the History of Science

OG/jj
Enclosures

HARVARD COLLEGE OBSERVATORY
Sesquicentennial Year 1989

SMITHSONIAN ASTROPHYSICAL OBSERVATORY
Centennial Year 1990

mouvement de
à l'heure.

($\frac{1}{9}$)

Fig. 1.

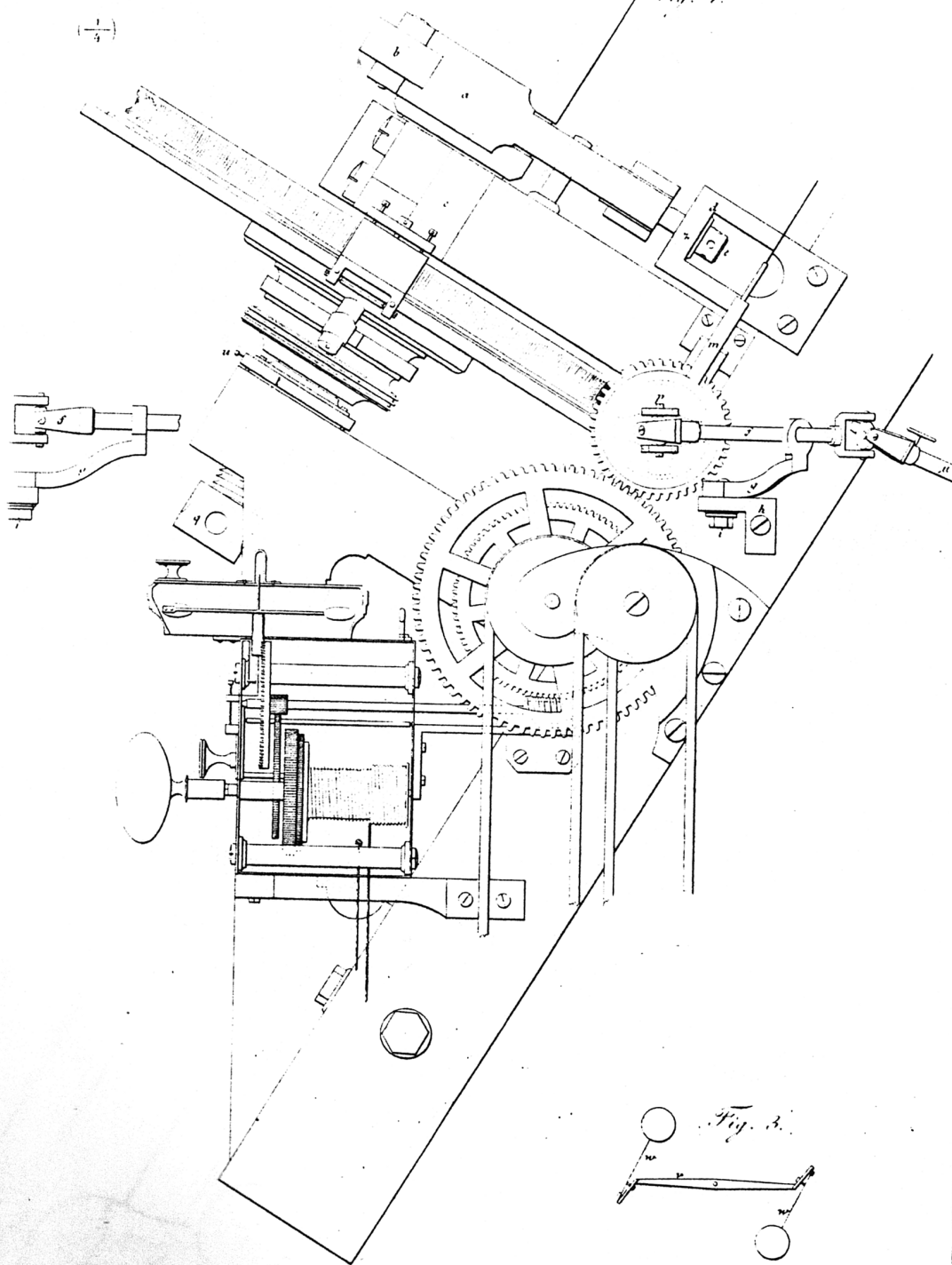
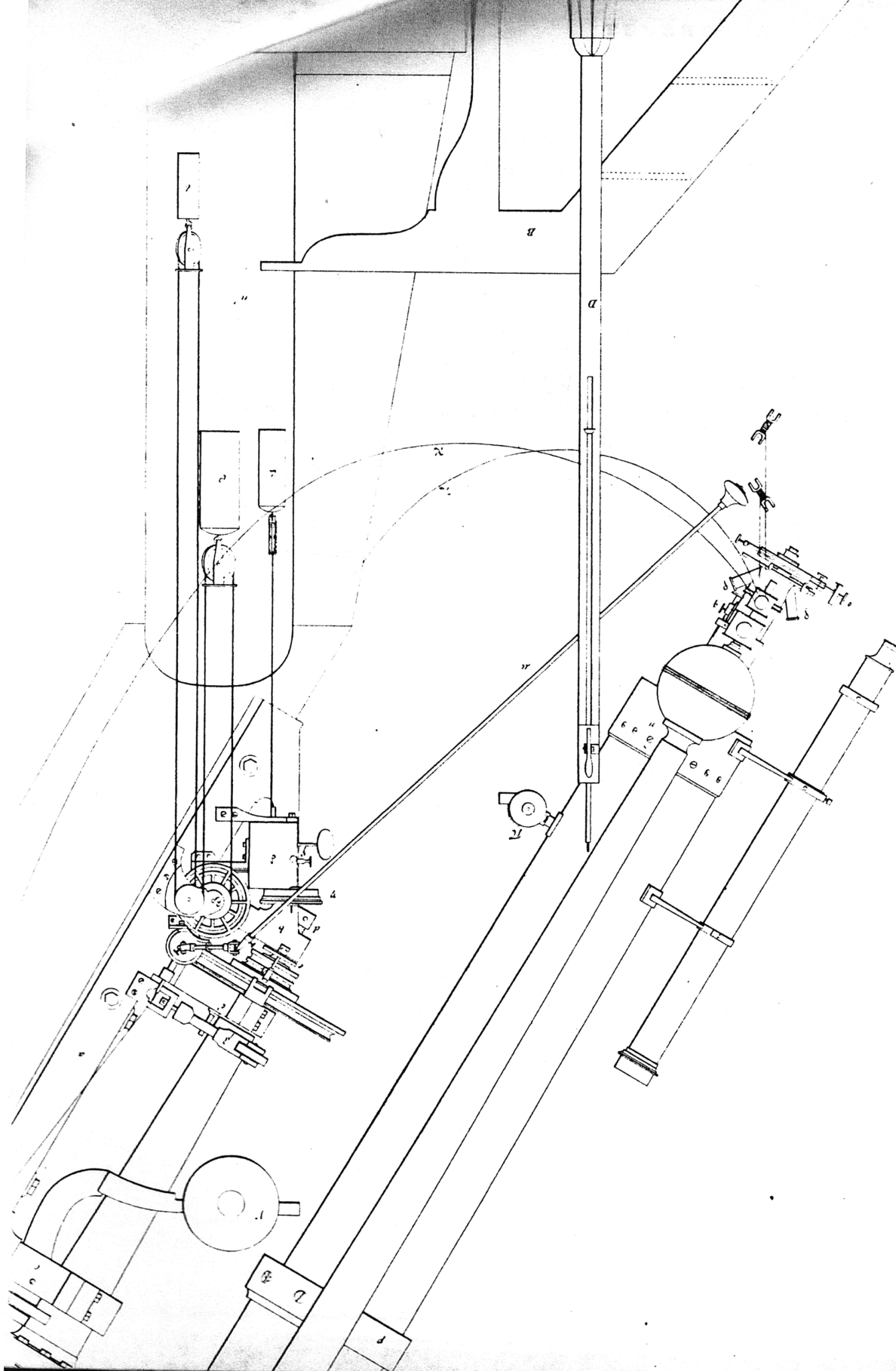


Fig. 3.

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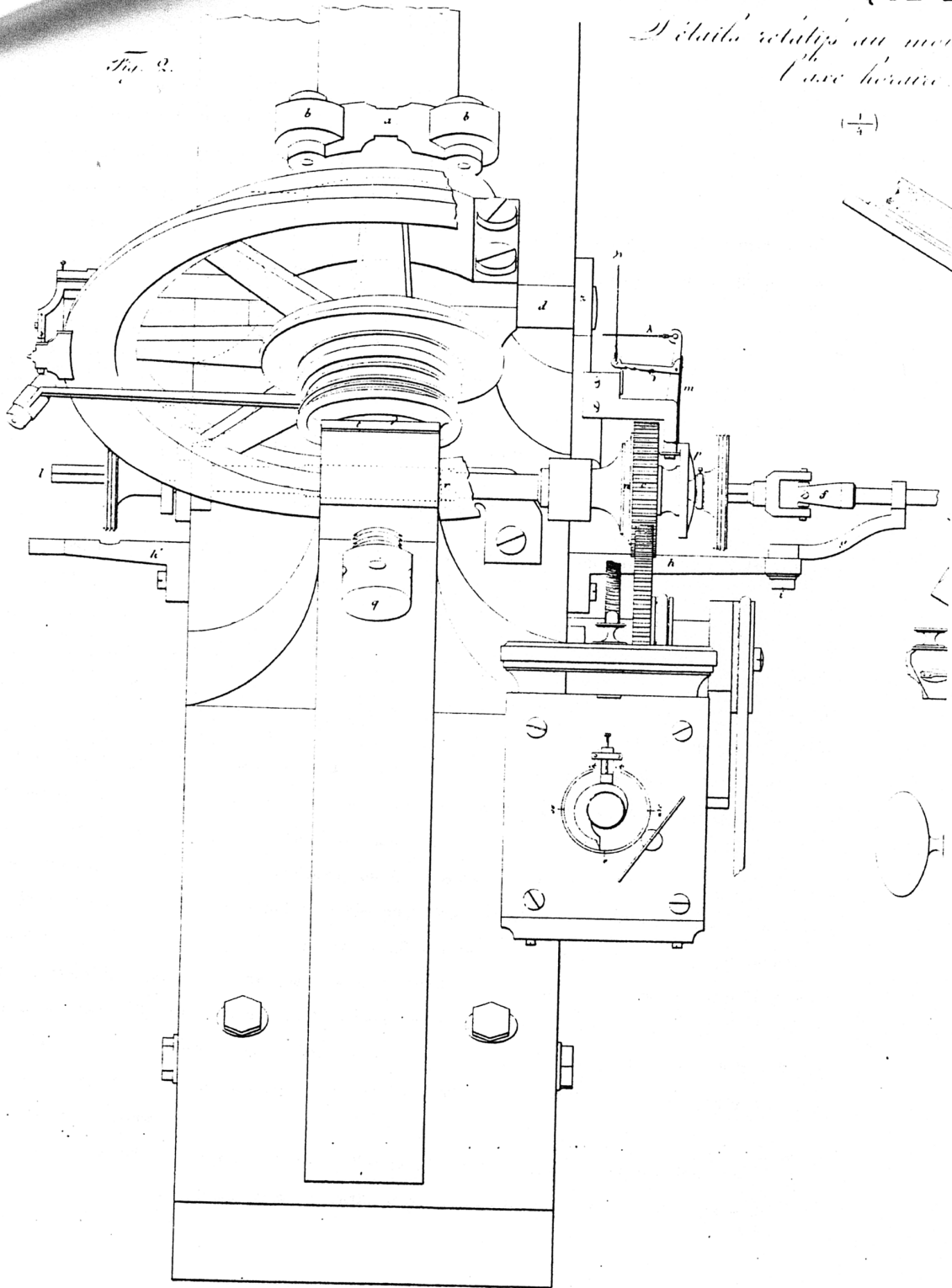
Gravé par A. Moysen



Détails relatifs au mouvement horaire.

($\frac{1}{4}$)

Fig. 2.



peu, pour produire l'engrenage le plus parfait des filets r , de la vis sans fin, dans la cannelure du cercle horaire.

- 5) La grande vis q agit immédiatement sur la plaque de métal de cloche t , dont la surface supérieure s'oppose au bout convexe de l'axe horaire. Cette plaque se termine en une petite boîte remplie d'huile, et qui préserve le bout de l'axe contre la poussière et contre la rouille. On fait entrer l'huile par une petite ouverture dans la face supérieure de la plaque, ouverture qui est fermée par la vis u .
- 6) Dans la figure 3, on voit le balancier centrifuge. Le fléau horizontal v est de laiton, et a deux petits bras contre lesquels les deux lamelles élastiques en acier, w , sont fixées, qui portent les deux lentilles de cuivre. L'ajustement de position des lentilles se fait à l'aide des deux vis qui agissent entre chaque lamelle et le bras correspondant.

L'appareil micrométrique.

L'appareil micrométrique que feu M. Fraunhofer avait exécuté pour l'instrument de Dorpat, était composé a) d'un micromètre filaire; b) d'un micromètre réticulaire composé d'un système de lignes, tracées sur une verre plan et illuminées obliquement; c) d'un micromètre de cercles concentriques, tracées et illuminées comme b); d) de quatre micromètres annulaires, à anneaux doubles ou simples. L'expérience m'a fait voir que les micromètres b) et c), quoique d'une exécution distinguée, ne sont effectivement d'aucun usage. Car dans tous les cas de l'application de ces deux appareils, le micromètre filaire mène plus directement au but et avec avantage, quant à l'exactitude. Par cette raison, nous avons renoncé à ces deux micromètres, pour l'instrument de Poulkova, et notre appareil se compose du micromètre filaire et des micromètres annulaires.

On a regardé les micromètres annulaires, de la construction de Fraunhofer, à anneaux d'acier suspendus sur un verre plan, comme indispensables pour l'observation des objets nébuleux les plus faibles, des comètes etc. Je puis dire que l'expérience de 20 ans ne m'a jamais donné l'occasion d'employer le micromètre annulaire; car j'ai trouvé que tout objet céleste, visible dans le champ obscur de la lunette, quelque faible qu'il soit, est aussi mesurable à l'aide du micromètre à fils luisants. Ceci a été justifié encore en 1843, par les observations de la comète de M. Faye instituées par M. O. Struve aux mois de mars et d'avril 1844, à une époque, où la comète avait disparu dans tous les télescopes des autres observatoires de l'Europe.

Je ne donnerai ici, ni une description détaillée du micromètre filaire, ni une exposition de son usage. La construction de l'appareil est connue; et quant à la méthode de s'en servir, j'en ai parlé dans l'in-

les directions de la verge et de la vis, et même au delà de cet angle. Les dessins indiquent comment cette double clef est placée et supportée, pour le mouvement du cercle horaire. Quant aux verges qui s'appliquent sur l'arbre de la vis du mouvement en déclinaison, nous avons déjà indiqué, p. 186 et p. 188, que nous n'en faisons aucun usage.

Détails relatifs au mouvement de l'axe horaire.

Pour mieux rendre intelligible ce que nous avons dit dans les articles qui traitent du mouvement de l'axe horaire, nous ajoutons encore la planche XXXV. *B*, qui représente sur une échelle trois fois plus grande, ou d'un quart de la grandeur naturelle:

fig. 1. l'extrémité de l'axe horaire avec l'horloge, vue du côté oriental,

fig. 2. les mêmes parties vues du côté méridional,

fig. 3. la section horizontale du balancier centrifuge de l'horloge.

Il serait superflu de donner une explication détaillée de cette planche, les dessins parlant eux-mêmes. Je me borne donc à quelques indications particulières.

- 1) L'anneau *a*, avec les deux roulettes *b*, qui sert à attirer l'axe horaire contre la moitié inférieure du coussinet *c*, est tendu par la lame d'acier *d*, dont les extrémités sont saisies par deux cadres *z*, fixés aux parois verticales du lit. La tension est produite et réglée à l'aide de la vis *e*, qui traverse le milieu de la lame.
- 2) La double clef de Hooke est représentée en *f*. Elle est supportée par l'appui *g*, qui communique avec le bras fixe *h*, à l'aide d'un pivot vertical. Sur ce pivot tourne la pièce *g*, mais elle se fixe par l'écrou *i*, aussitôt qu'on lui donne la direction convenable, c'est-à-dire celle où l'arbre de la clef fait deux angles égaux, d'un côté avec l'arbre de la vis sans fin, de l'autre côté avec la direction de la verge μ , qui se prolonge vers l'endroit de l'observateur. On voit, fig. 2, le bras correspondant *h'*, qui sert à fixer l'appui *g*, si la clef est à placer du côté occidental, à l'autre extrémité de la vis sans fin, en *l*.
- 3) *m* est le levier qui produit la séparation entre la tête dentée *o* et le cône *n*, assis sur l'arbre de la vis sans fin. Le levier porte une petite roulette à l'extrémité inférieure. On voit qu'en tirant la corde λ , les petites entailles du second bras ρ du levier s'accrochent sur une plaque aiguë du porte-levier. Dans cet état, la tête *o* est séparée du cône *n*, mais elle tourne toujours avec le rouage de l'horloge, parce que la petite roulette n'oppose aucun obstacle au mouvement. La seconde corde κ délivre le bras ρ de son crochet; et dans cet état, le ressort *p*, en forme de croix, produit aussitôt la réunion requise de la tête *o* avec le cône.
- 4) A l'aide de la grande vis d'acier *q*, on peut lever et faire descendre l'axe horaire, tant soit

de devant, à dents verticales et situé sur le même axe, engrène dans la tête dentée de la vis sans fin du cercle. Cette tête est assise sur l'arbre cylindrique de la vis, au moyen d'une douille qui peut glisser le long du cylindre, en sorte que tantôt elle communique son mouvement à la vis, tantôt elle tourne sur l'arbre, sans que celui-ci participe au mouvement. C'est que la tête a un creux conique qui s'assied sur un cône concentrique fixé à l'arbre de la vis. Dans cette réunion, la tête et le cône forment une seule pièce, par l'adhésion des surfaces de contact. Un levier assis sur le corps du lit α , sert maintenant à mouvoir la tête le long de l'arbre, et en détruit ainsi la réunion avec le cône, selon la volonté de l'astronome. Pour ce but, deux cordes sont attachées au levier, qui se prolongent jusqu'au siège de l'observateur. S'il tire la corde κ , la tête poussée par l'action d'un ressort, se place sur le cône, et l'horloge agit sur la vis du cercle. S'il tire au contraire la corde λ , la tête se sépare du cône, et l'action du ressort est arrêtée. Dans ce dernier cas, l'horloge qui continue sa marche, ne fait que tourner la tête sur l'arbre de la vis, et l'astronome produit alors la rotation de l'axe horaire dans les deux sens opposés, à l'aide de la verge μ . On reconnaît facilement tout l'avantage de cet arrangement ingénieux et simple, quand il s'agit de placer un fil du micromètre exactement sur une étoile, par un mouvement dans le sens de l'ascension droite; l'action de l'horloge étant aussi prompte que régulière, dès l'instant que l'on tire la corde κ .

La vitesse de l'horloge peut être modifiée à volonté, à l'aide d'une plaque excentrique, visible en γ , au-dessus de la clef qui monte l'horloge. Cette plaque lève et descend le pivot du balancier.

Les verges du mouvement micrométrique.

La planche XVII nous montre, du côté oriental de la pierre, 7 verges de fer, horizontalement suspendues sur des crochets qui sortent de la doublure du mur.

Deux de ces verges se terminent en crochets à bourrelets, et servent à exécuter les mouvements gros de l'instrument, dans le cas que les leviers du tube sont trop élevés au-dessus du plancher, pour les atteindre de la main.

Trois des verges appartiennent au mouvement de la vis sans fin du cercle horaire, deux au mouvement de la vis de rappel en déclinaison. Ces verges sont de différentes longueurs, selon le besoin. La verge qui est en place à l'instrument, repose sur un montant à crochets, supporté par un trépied D . Dans l'intérieur du montant il y a un bâton en cuivre, qui se termine en haut dans un croissant couché, pour y placer la verge, en cas que le télescope est dirigé sur des étoiles très basses. On change la hauteur du bâton à volonté.

La réunion d'une verge quelconque à l'arbre de la vis à mouvoir se fait par une double clef de Hooke, qui permet de produire le mouvement de la vis, même dans le cas d'un angle droit entre

cheville, indiquée au-dessus de c , presse deux roues d'acier contre l'axe horaire et en diminue le frottement dans le coussinet supérieur.

Par ces arrangements, le mouvement du télescope autour de l'axe horaire est devenu d'une facilité admirable dans toutes les saisons de l'année; quoique en hiver, pendant les froids excessifs, le frottement augmente, à la suite de la viscosité de l'huile gelée sur les coussinets.

L'horloge.

Une pièce d'horlogerie est appliquée à l'instrument, pour produire un mouvement spontané du télescope autour de l'axe horaire, uniforme et égal au mouvement des astres autour de l'axe céleste. Elle est composée de deux parties, 1) *l'horloge*, 2) *le rouage de transport*, pièces qui sont assemblées au côté oriental du lit a , vers l'extrémité inférieure.

L'horloge δ est enfermée dans une boîte de 6 pouces de haut, sur une base carrée de 5,2 pouces de côté, et se compose de trois roues. Le mouvement en est produit par le poids ζ , et se règle par un balancier centrifuge qui porte de petites lentilles de cuivre, réunies à un bras horizontal et rigide, par des lamelles élastiques. Ces lentilles s'éloignent du pivot en rotation, par la force centrifuge, et se frottent contre la paroi intérieure, conique et polie de la petite boîte η , de métal de cloche. C'est précisément ce frottement qui produit l'uniformité du mouvement de l'horloge. Selon la position plus ou moins élevée du pivot du balancier, le frottement des lentilles change, à la suite de la forme conique de la boîte η .

Le rouage de transport ϵ a un double but:

1. de transporter le mouvement de l'horloge à la vis sans fin qui agit sur le cercle horaire;
2. de vaincre la résistance qu'éprouve cette vis dans la production du mouvement du cercle horaire.

Il est composé d'un axe horizontal qui porte deux hérissons et une poulie à pointes, sur laquelle le poids θ , de 41,3 livres, est suspendu, à l'aide d'une corde sans fin, tendue par le petit poids ι de 8,5 livres. Le poids θ tend à produire un mouvement de rotation dans le rouage de transport, et comme celui-ci communique avec la tête dentée qui se trouve sur l'arbre de la vis sans fin du cercle, le même poids θ tend à produire un mouvement du cercle horaire. Le rayon de la poulie de la corde étant de 1,46 pouces, et celui du hérisson qui transporte le mouvement, de 3,70 pouces, il s'en suit que la force exercée sur la périphérie de la tête dentée, est de 6,5 livres; force qui suffit à vaincre la résistance. Dans cet état, l'horloge produit le mouvement, en transportant la rotation de la roue de champ qui travaille sur le pignon du balancier, à une vis sans fin à filets doubles et obliques. Cette vis travaille sur le hérisson de derrière, à dents obliques, du rouage de transport, tandis que le hérisson