THESIS,

DESIGN FOR A HELIOSTAT,

FOR THE DEGREE OF

SCHOOL OF MECHANICAL ENGINEERING,

BY

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Having had occasion to use a heliostat and not caring to incur the expense of purchasing one at the usual price, it occurred to me that an instrument possessing the essential qualities of the finer instruments, but much cheaper and simpler, would answer quite well enough for photo-micrography by sunlight. No doubt many besides myself have hitherto been prevented from giving the heliostat a fair trial in this kind of work, because of inability to procure one at a reasonable price. This being the case, it was determined to design an instrument that while being moderately cheap, should be simple and so adjustable as to eliminate as many of the errors of construction as possible, quickly put in motion, easily kept in order, and requiring but little
attention after once being properly set and regulated.

The following expression in as few words as possible,
both the mathematical and mechanical solutions of the problem
set OA (fig 1) be an axis parallel to that of the earth and
turned by a suitable mechanism at the rate of one revo-
lution in twenty-four hours. BC is a pointer attached to
OA so that it takes the motion of OA; then if the angle BOC
is made equal to 90° + φ - the sine's declination, according as
it is north or south, BC will revolve in the place of the sun's
apparent motion; and if BC is set to a point at the sun,
it will follow the sun, remaining approximately parallel
to the sun's rays throughout the day. DE is a mirror hung
on an universal joint, permitting it to take any position
whatevers about the point D. DE is a perpendicular to the
mirror at D, and is attached to the pointer at Q, so that
the length of DE may vary. QC is made equal to the distance
of D and remains CD. QEC is, therefore, an isosceles triangle.
Thus if the plane of the arc be made to coincide with the plane of the meridian through the place, the instrument leveled and the angle of OF with the horizontal be made equal to the latitude of the place, OA will be parallel to the earth's axis. The pointer BC has a movement about O in the plane of OA and BC of 33 1/2° either side of its position perpendicular to OA and is clamped in any desired position by the screws at O. The pointer BC is fixed at C, and pivoted to a collar which is free to slide and turn on CD; the pointer also turning in its bearings X and Z. The mirror is pivoted at the extremities of its horizontal diameter, to the two branches of the upright I which is free to turn in the plane J. The point J is kept at a constant distance from O by means of the parallelogram of R E L. The sides of and BC are equal to DC; FR is extended above to receive the upright I, and BC bow so as to serve as a vertical axis.
The center of the axis $O$ and $I$ and that of motion at $O$ (which coincides with the center of the arc) are in the same vertical line, $OI$ being atención above the bearing to receive the two long sides of the parallelogram. By revolving the parallelogram about the vertical axis $IO$, we may change the direction of $OD$ and hence the reflected ray in azimuth, the axis being clamped in position by the thrust screw $S$. By rotating the parallelogram about its joints the attitude of $OD$ is made to vary and kept in position by the thrust screw $S$, therefore $O$ describes aero of circles with $O$ as center.

This arrangement for changing the direction of the reflected ray quickly, is very convenient when using oblique light and to throw the light upon the exact spot where needed; it serves, also, if the instrument is not in adjustment to correct the deviation of the ray, with but little trouble. The revolution of the axis OA may be accomplished with any good spring clock works, the hand and mechanism of the hand being removed.
and the works placed in a case specially provided for them. This case is carried by the block E, the minute hand arbor being at right angles to OA, that is to say, perpendicular to the plane of the arc m.n.o. on the arbor is placed an endless screw V, which engages a wheel on OT having twenty-four teeth. Twenty-four revolutions of the screw will then cause one revolution of OA, and as the arbor makes one revolution per hour, we have the desired daily rotation of OA. The other end of the minute hand arbor extends through the opposite side of the clock case and carries a pointer, on the case is a mark to which the pointer should return every hour so that we may regulate the clock by means of any time-piece. If it should be so desired, that the hour hand mechanism might be retained and the axis extended through the opposite face carrying an hour hand, and then if the face of the cover be divided into
hours and minutes the heliostat becomes a time piece as well, but for ordinary use this would not be advisable and would add to the cost of the instrument.

This whole should be secured to a hard-wood base provided with three leveling screws and a level (not shown in the figure). The various parts may be constructed of whatever material appears best for each, cast and rolled brass being probably the best for the main pieces, and Stub's polished steel wire for the axle, screws, pivots, etc.

To put the heliostat in operation after having placed it in the meridian and leveled it, the set screws S and O are loosened and the pointer is made to point directly at the sun by turning it about OA and O until the shadow of BE is seen on the small disk y; set the screws S and O and the pointer is carried around by OA in its daily revolution. The shadow not only serves to get the sun's declination and altitude without the graduations, but
gives us a means of regulating the clock. If the instrument is started and after some time has elapsed the shadow is seen on the disk, we infer that the pointers is gaining or losing on the sun, according as the shadow is on the advance or rear side of pointers; and the clock may be regulated to correspond.

The mirror should be a plane silvered glass as thin as is consistent with proper strength, a polished metal mirror would no doubt be as good if not superior to the silvered glass on account of having but one reflecting surface, but would be more expensive, while the glass answers the purpose admirably. The reflection from the upper surface being of no special consequence in photographic work.

The mirror is sunk flush with the rim of its holder, to the lower surface of the holder is attached the perpendicular $CD$. If $CD$ is perpendicular to the holder.
and the reflecting surface of the glass mirror is not perpendicular to the upper surface, O D would not be perpendicular to the reflecting surface as it should be.

This is provided for in the following manner: a', a'', a''' are three screws in the ring of the holder, the screw heads being wider than the thickness of the ring, extend over the mirror and hold it in place. The holder is made somewhat deeper than the thickness of the glass to allow three small springs to be placed under the mirror opposite the three screws, tending to push the mirror out of the holder against the screw heads. After the mirror is put in place it may be tested and adjusted in the following manner: Remove holder containing the mirror from the support H J K (fig 2), lift out the support from the bearing fr and insert the perpendicular of the mirror instead (x and O D being made of the same sized wire) place the instrument.
so that the direct sun light will strike the mirror and the reflected spot of light be thrown on some surface as the ceiling, revolve the mirror in its position and if the reflected spot of light vibrates back and forth it will indicate that the reflecting surface is not perpendicular to O. The three screws may then be adjusted until the spot remains steady while the mirror revolves. It may then be returned with its support to its proper position.

The mirror can be made elliptical in shape its major axis parallel to the pointer O and about twice as long as the minor axis, by this we would have the reflected spot about circular whereas if the mirror is circular the spot would be elliptical.

Notes. The movement is not exact for the following reasons.
1. The pointer is keeping mean solar time, which is gaining or losing on true solar time.

2. The Sun is apparently going north or south from the equinoxes; hence if the pointer is set at any moment with the correct declination, at a later time the Sun will have varied in declination, while that of the pointer remains constant.

But as the instrument is in use only from 6 to 7 hours out of the 24, these errors are very much smaller than the errors of constructions, and are practically zero.