THE EFFECT OF RAIL-ROAD TRAINS IN TRANSMITTING VIBRATIONS THROUGH THE GROUND.

PROF. H. M. PAUL.

[ABSTRACT.]

The experiments were made in Washington, U.S.A., in connection with the examination of proposed new sites for the *U. S. Naval Observatory*, and their object was to determine whether the vibrations from rail-road trains near to some of the eligible sites would injuriously affect the reflection observations from the surface of mercury, which form an important part of meridian work.

A telescope of 3.25 inches aperture and 48.5 inches focal length, with an eye-piece magnifying about 135 diameters, was used in the observations, and was sufficient to give a sharp test of reflected images.

A box about 10 × 14 inches and 1 inch in depth, containing about 20 pounds of mercury two-thirds saturated with tin to insure greater steadiness, rested on three screws set in a heavy plank which was firmly screwed to the top of a post sunk about 4.5 feet in the ground, with the earth rammed as hard as possible about the post, the whole constituting the reflecting apparatus used at each station, and to which the earth vibrations were transmitted. After one night's trial it was found necessary to protect the mercury

from surface breezes by a plate-glass roof which, though it increased the number of images by the successive reflections from its optically imperfect faces, and made each one much fainter, yet gave a much sharper test of definition by the system of separate images in close proximity.

The observations were made in the evening on the reflected image of *Polaris*, thus avoiding the necessity of moving the telescope tripod to follow any star situated further from the pole.

The places of observation were four in number, and their distances from the nearest point of the rail-road were approximately as follows, in hundredths of a mile;

	miles.
A,	0.29
B,	0.83
C,	0.93
D,	0.81

Without going into the detailed results of the observations at each place, the following remarks will give a fair idea of those results.

The post was set in the ground as nearly alike at each place as possible, the only difference being in the character of the soil, that of stations A and D being a compact pebbly gravel, that of B a very hard tough dry clay, and that of C a somewhat more moist and softer clay in which, for this reason, broken stones were also rammed in around the post in setting it.

At the site nearest the rail-road, station A, 0.29 miles distant, a fast train going down grade at about 40 miles per hour made such a disturbance that the system of images in the field was broken up and spread out into a boiling patch of confused waves more than 1′ in diameter. In one case I detected the approach of this train at station A by the beginning of the trembling of the images before I could hear the train approaching, at that time there being only a slight breeze blowing from the station towards the approaching train. A slow train up grade at about 15 or 20 miles

per hour also made a marked trembling and confusion of images, and both these trains caused sufficient disturbance to prevent a meridian reflection observation for about 2½ or 3 minutes while each train was passing.

At stations B and C, distant respectively 0.83 and 0.93 miles, the effects were in some respects about the same, and in others quite different. At both stations the effect of the fast trains down grade was about the same in degree as that of the slow trains at station A, and sufficient to prevent any meridian reflection observations. But, while at A and B the disturbing effects had been a gradual increase to the maximum and corresponding uniform decrease again in the case of all the trains, with a duration in all cases of between 2 and 3 minutes, at C the effect of the fast train was quite irregular, the mercury tending to settle down two or three times and then being shaken up again during the 2 or 3 minutes, and the effect of the slow train only lasted about 1 minute instead of 2 or 3 as at B. This, coupled with the irregularities of the fast train, would possibly indicate that station C, 0.93 miles from the rail-road, was near the edge of the belt of ground over which the disturbance extended. At both B and C, while the fast trains shook the mercury enough to prevent reflection observations, the effect of slow trains up grade, although distinctly noticeable, was not more than frequently has to be borne from surface breezes or other local disturbance in an observatory, and was not enough appreciably to hinder satisfactory bisections of the reflected image of a star.

At station D, distant 0.81 miles, that is, slightly nearer than B and considerably nearer than C, there was no effect from the fast trains down grade, except for about 10s. or 15s. when the train seemed to be crossing a small bridge about a mile from D, but even then this disturbance from the fast trains was very much less than from the slow ones at B and C, both of which were more distant from the railroad. The soil in which the post was set at D was almost exactly the same as at A, and the most probable explanation of the very marked difference of distrubance

here and at the other places is the presence of a small ravine or valley, about 50 or 60 feet deep, between D and the rail-road and within 300 or 400 feet of D, in which case, if the vibrations at this distance from the railroad did not reach very deep below the surface, the ravine would tend to cut them off.

The four stations were all on the same side of the rail-road, and all within a circle of about 2 miles in diameter, and, as far as indicated by excavations for railroad cuts and the digging of wells, they all appear to rest on similar strata of clay and gravel to a considerable depth.

Experiments were also made on two other sites, to test the effect of carriage-driving on a public road, and it was found that a hack carrying four persons and drawn by two horses, driven up and down on a gravel road about 400 or 500 feet from the instrument, made a temporary shaking of the mercury whenever a wheel struck a stone or hollow, and also while crossing a small wooden bridge about 500 feet distant; but there was no serious continuous disturbance till the carriage approached within 200 or 300 feet of the instrument.