has shown that the error due to settlement, other things being equal, is proportional to the length of line run. In ordinary levelling operation, the character of the ground affects the work in a different way, the feet of the observer compress the ground near the tripod legs, and displace the line of sight in the interval of time between levelling and reading the rod. To obviate this, Colonel Goulier has recommended that two of the legs be always placed parallel to the line of sight. The use of the mirror, already noticed, would also remove this source of error.

The largest source of *observational errors* is believed to be due to the want of careful centering or reading the bubble. Every leveller should know what rod reading is covered by a range of one division of his bubble at a given distance of, say 100 feet, in order that he may fully appreciate the effect of errors of this kind.

When the illumination of the two ends of the bubble is different, an error in centering is almost sure to follow, there being a tendency to bring the bubble too much towards the light. Error is also introduced through parallax, the bubble being viewed obliquely to its length. It has recently been urged by a German observer—Dr. Reinhertz—that the bubbles should be viewed in profile. Clearness of the glass and distinctness of the graduations have much to do with the accuracy of bubble readings. Errors of rod reading are more common with a target than with a speaking rod. The best check on the former is for both rodman and leveller to make independent readings. Where three wires are used, errors with self-reading rods are of very rare occurrence. The mean of the three readings is also without doubt more accurate than a single reading on a target rod. It does not by any means follow that because a target rod reads to .001 of a foot that the reading is accurate within that limit. A difference in the illumination of the rod will also affect the relative accuracy of the readings, and a line running east and west will probably show different results, according as it is levelled in the forenoon or afternoon.

Under *personal errors* we have merely to note that each observer has his own peculiarities, which will largely affect the resulting difference of level over a great length of line. This is in fact the personal equation of the observer. To quote from the report of the Chief Engineer, U. S. A., for 1884: "These discrepancies vary with differ-
"ent observers, and are not even constant for the same observer, are
"nearly proportional to the distance, and seem to be independent of
"the nature of the ground, the direction in which the work is done,
"the season or the manner of supporting the rod." The results of some recent levels on the Mississippi survey go to show that this personal equation may be somewhat evanescent, particularly with young observers, and that every line of levels should be duplicated in opposite directions by the same observer within the shortest possible limits of time, in order to reduce the probability of change in the personal equation. With skilled observers of long practice, this habit is probably a constant from year to year.

For the effects of *atmosphere errors* I cannot do better than quote from Professor J. B. Johnson, who was for some time engaged on work in connection with the Lake survey. (Van Nostrands Mag. for Oct. 1883.)

"Errors from this source may be classified as coming from: 1,
"Wind; 2, Tremulousness; 3, Variable Refraction.

"1. Wind generally shakes the instrument, and makes the holding
"of the rod difficult or impossible. For two seasons I have used a
"tent on windy days to protect the instrument, and with great success.
"Good work can be done in this way so long as the rod can be held.
"We also have large square canvas umbrellas that can be set on the
"ground to the windward of the instrument, and these effectually
"shield them in ordinary windy weather.

"The tents used were wall-tents, 5 × 6 feet, and one 8-foot centre
"pole. A square iron frame, 3 × 3½ feet, sewed into the canvas near
"the top, formed the lateral support there. It was held down by six
"or eight steel pins, 18 inches long and ½ inch diameter, with flat
"heads. These passed through iron rings sewed into the bottom.
"There were openings for the line of sight and a flap for the observer
"to enter and pass out with the instrument. These tents were made
"to be used on Gulf coast at a very windy season, when one half the