caused by a shifting of the reflector inside the telescope, by means of which the field is illuminated, which produced an apparent shifting of the image of the spider lines, unless the eyepiece was very accurately focused for the observer’s sight. The simplest and best way to find the equation between two observers is to let one observe the transits of stars over half the wires in the telescope, and the other observe the transits over the remainder, each taking care to refocus the eyepiece for himself in order to avoid the above- mentioned source of error. The single transits reduced to the middle wire give immediately the equation; and, in order to eliminate errors in the assumed wire-intervals, each observer uses alternately the first and the second half of the wires. In longitude work, the two observers generally after the completion of a certain number of nights’ work exchange stations and commence a new set of observa­tions; the mean of the two results thus obtained should be free from the effect of personal error, provided that the errors of both observers have remained constant the whole time. It is therefore advisable to let the observers compare themselves, at the beginning,\_ middle and end of the operations, and, if possible, at both the instruments employed. A useful check on the results is afforded by simultaneous experiments with one of the instruments contrived by C. Wolf, Kaiser and others, by which the absolute personal error of an observer can be determined. Though differing much in detail, these instruments are all constructed on the same principle: an artificial star (a lamp shining through a minute hole in a screen mounted on a small carriage moved by clockwork) passes in succes­sion across a number of lines drawn on oiled paper, while an electric contact is made at the precise moment when the star is bisected on each line by the carriage passing a number of adjustable contact makers. The currents thus made register the transits automatically on a chronograph, while the observer, viewing the apparatus through his telescope, can observe the transits in the usual manner either by eye and ear or by chronograph, thus immediately finding his personal error. ' These contrivances have sometimes been used to educate pupils learning to observe, and experience has shown that a consider­able personal error can be generally somewhat diminished through practice. By using Repsold's self-registering micrometer, which enables the observer to follow the motions of the star with a movable vertical wire which automatically registers its passage over certain fixed points in the eyepiece, the effect of personal error is almost completely eliminated. In the determination of the difference of longitude between Potsdam and Greenwich in 1903 the two observers with their instruments exchanged stations in the middle of the opera­tions, and the sum of their personal and instrumental equation was 0∙0003 with a probable error of = 0.0035.

Literature.—General treatises on spherical astronomy, such as Brünnow's *Lehrbuch der sphärischen Astronomie* (3rd ed., Berlin, 1871 ; trans. into English and several other languages) and Chauvenet’s *Manual,* treat very fully of the numerous methods of deter­mining time by combination of altitudes or azimuths of several stars. For telegraphic longitude work sec the *Publicationen des kön. preussischen geodätischen Instituts·,* the *Reports* of the United States Coast and Geodetic Survey; vol. ix. of the *Account of the Great Trigonometrical Survey of India;* and *Report of the Chief Astronomer, 1905* (Ottawa, 1906), which gives a useful review of recent longitude work in the Pacific and adjacent countries. On personal errors see Dreyer, *Proc. Roy. Irish Acad.* (1876), 2nd series, vol. ii. p. 484, and “ Recherches sur l’équation personelle par Μ. F. Gonnesiat ” in the *Trav. de l'observ. de Lyon* (1892), vol. ii. (J. L. E. D.)

**TIME, STANDARD.** Local time is determined by the relation of the meridian of a place to the sun. Noon at any place is defined as the moment when either the true or mean sun passes the meridian of that place, according as apparent or mean time is used. Practically, the use of mean time is now universal, so that we may regard the mean sun as that by which noon is determined. As the earth revolves, all its meridians are brought under the sun in succession or, relative to the earth, noon con­tinually travels around the earth, making the circuit in twenty- four hours. It follows that noon, and therefore any other hour of the day, is later by four minutes for every degree of longitude towards the west, so that a watch carried east or west will be found to deviate from local time by an amount proportional to the change of longitude. Before the time of railways this devia­tion was not productive of inconvenience. But when railway travelling became common, train schedules had to be more exact than those of a mail coach, and the traveller was rapidly carried to places where the local time continually deviated from that shown by his watch. The use of such time thus had to be modified in places where intercommunication with others of a different longitude was frequent. Thus arose a practice on the part of railways of using the time of some central or important city on its line for all places not too distant, which time would naturally be adopted by the inhabitants of the region through which it passed. For a similar reason, in countries which did not extend through a large fraction of an hour of longitude, it was natural to use the time of the capital throughout all or a large part of its extent. Thus Greenwich time has long been in use throughout England, and all the railways of France are run by Paris time. But inconvenience was still unavoidable in passing from one country to another, or in travelling through long stretches in the same country. The inconvenience was especially felt in the United States, where every railway, and even every long stretch of several great railways, had its own time system. Thus it happened not infrequently that in a single station clocks would be found set to the time of three different meridians, one for the road toward the east, another for the road toward the west, and a third for the meridian of the place, or local use.

A device now being generally adopted to do away with this confusion was planned in 1878-1879 by Mr (afterwards Sir) Sandford Fleming, and published in the *Journal of the Canadian Institute of Toronto* for 1879. On the initiative of this organiza­tion, Mr Fleming’s proposals were officially communicated to the leading governments of the world with a view of securing an international unification of the method of designating the hour of the day for common use. Naturally connected with the proposal was that of a prime meridian, from which all longitudes should be reckoned. United States invited an international con­ference, which was held in Washington in 1884, for the purpose of proposing a standard meridian to which longitudes and times should be referred.

Before this conference was called the railway managers of the United States, after long discussion, adopted the system. Its fun­damental idea was that twenty-four standard meridians should be established 15° apart in longitude, starting from the meridian of Greenwich and extending round the globe. Then on each meridian the local time would differ from Greenwich time by some entire number of hours. At every point of the globe the time to be adopted for common use was that of the nearest standard meridian. These meridians would therefore mark the central lines of twenty-four zones, within each of which the time to be adopted would be uniform, but which would change by an hour on passing from one zone into another. The inhabitants of each zone naturally use the time of the zone instead of their local time, the maximum difference between the two being half an hour.

When the system was first established in the United States a delicate legal question arose as to whether the business of banks and courts should be legally adjusted to the new time. This was soon settled by state laws making the standard time legal within the limits of each zone. A similar system is being adopted in Europe, the standard meridians being those of 15°, 30°, &c., east of Greenwich. France, however, still adheres to Paris time,@@1 but Belgium and Holland use Greenwich time, and Switzerland, Italy and central Germany use the time of 15° E., and therefore one hour in advance of that of Greenwich. This is termed mid-European time.

The system we have described is that adopted for the purposes of the railways and of daily life. For scientific and for some international purposes yet other modifications are desirable. An important distinction must be made between the cases in which convenience requires that the time have some relation to the hour of the day, and those where no such relation is required. The former is the case in designating acts or occurrences which depend upon our daily routine of rest and wakefulness. But if nothing is necessary except the designation of some moment of absolute time, irrespective of our daily routine of life, then only a single measure for the whole world is necessary. At the Washington Meridian Conference of 1884 it was proposed that Greenwich time should be adopted as a standard for the whole world in all matters of this class, especially in astronomical practice and in cable despatches. But this system does not seem to have been extensively adopted outside of astronomy, the

@@@1 A bill adopting Greenwich time in France, which had already passed the Chamber of Deputies, was favourably reported on in the Senate in December 1910.