a second it is found that an exchange of thirty signals gives a probable error for the mean difference of the two chronometers of less than ±.002. Small as this quantity is, it includes error of scaling, irregular running out of tape, irregularity of clock beats, and differential rate.

Compared with the many other quantities—star places, level readings, temperature with its hidden effects on instrument and chronometer, errors of observation, personal equation—entering into the determination of the difference of longitude, the probable error of an exchange of time signals is almost a vanishing quantity. The same remark holds true for an exchange over land lines. Fig. 5 illustrates a cable record, both receiving and sending.

Clock Exchange on Land Lines.—Land line exchanges were made between Vancouver and Bamfield, Southport and the observatories at Brisbane and Sydney, the former fifty miles distant by wire, and the other 753 miles. Also between Doubtless Bay and the observatory at Wellington, 701 miles. The exchanges were effected without the interposition of relays on the line.

It was customary to allow both clocks to record over the wire at the same time and record on the chronographs of the two stations. This was a mere check on the actual exchange by arbitrary signals and to show the relative position on the chronographs of some one minute (the 60th second) of the one clock and some one minute of the other clock. Experience has long shown that a more accurate comparison between two clocks can be made by arbitrary signals, that is by breaking the local clock circuit as shown on the chronograph, and by that same depression of the key, breaking the main line and hence sending a signal to the distant station there to be recorded on the chronograph, than by simply allowing the clocks to record over the line. The particular merit of the arbitrary signals lies in the fact that in scaling the chronograph sheets the mind is and remains unbiased in making the measurements, whereas when scaling the record of the two clocks recording simultaneously on the chronograph, the mind involuntarily becomes biased after making one measurement. We know in advance what the remaining measurements should be. It is impossible to get rid of the influence of knowing in advance what to expect. This undesirable condition in exchange of clock signals is obviated by adopting the method of arbitrary signals. The measurements on the chronograph sheets as well as on the cable fillets were read to the one-hundredth of a second of time.

At the three observatories, Brisbane, Sydney and Wellington the Morse register with fillet of paper and two styles was used for recording the exchange of clock signals. It is somewhat surprising how tenaciously this form of chronograph is maintained not only at those observatories (Sydney had a drum chronograph too) but also at those in Europe. The cylinder chronograph is to one who has used both so manifestly superior for convenience of reference and reading and saving of time that it is difficult to understand why the Morse form is retained.

Rate.—Rate is one of the most difficult problems with which we have to deal in longitude work. It is not the magnitude of the rate, although a small rate is very desirable, but the constancy. This is the crux. A chronometer may have an apparently constant daily rate, yet the hourly rate for the twenty-four hours may and does vary. Again the rate is not the same when the current is on, as when it is off; the former condition obtaining when observing, and the latter the rest of the day. The rate deduced from two independent time determinations of the same night, when the temperature is practically constant for the clock during the time of observation, and the clock is in circuit with the battery only during that time, is seldom, if ever, the same as that obtained from day to day observations.

In our programme we have two independent time determinations for each night. Each set of transits is reduced to the epoch of the mean of the times of transit of the stars comprising the set. The rate which is applied for each transit to the mean epoch, and for which some magnitude must be assumed, is practically a vanishing