The Troubles of *Father Time*

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Everyone who reads this article—and no one can afford to miss it—will appreciate that meticulous accuracy in obtaining, keeping, and dispensing time is far from easy to attain.

Father Deppermann takes our readers behind the scenes at a great Observatory to show them how time is obtained from the stars. He tells them how and why it must be preserved with such great accuracy that it can be transmitted to others with an accuracy of at least one one-hundredth of a second. Each step has its own difficulties. The ingenious methods used to solve them show something of how scientists reason and work.

This paper will give you increased respect for "Father Time".

INTRODUCTION

One may be tempted to smile at the idea that, as "Father Time", I am worrying about the one-hundredth part of a second in this so-called "land of mañana", where one is inclined wrongly to think "it is always afternoon".

True it is that, locally, we rarely need time accurate to more than a minute. Furthermore, for ships at sea to fix their positions, the wireless broadcast of time, accurate to about half a second, is usually quite sufficient; but for geodetic work as well as for an increasing number of scientific purposes, time accurate to at least one-tenth of a second is imperative. In fact, for tracing the actual path of radio waves, for the determination of exact longitude, for the solution of the interesting question whether the continents are moving slowly relative to each other, and for many other problems, there is an insistent demand for time correct to at least the hundredth part of a second.

Few indeed, however, realize what a swarm of difficulties arise to prevent such accuracy. We have only to compare among themselves the corrections given by different first-class Observatories to their own signals with the corrections given the very same signals by other Observatories receiving them by wireless, to be convinced that, although such corrections are given to the *thousandths* of a second, and rightly so, we are really as yet none too sure of the *hundredths*.

We think that a brief survey of our own difficulties in maintaining accurate time will not only be interesting, but it will also give an insight into the principles and methods of scientific research.

We may group our considerations under three main headings: the *getting* of accurate time, the *keeping* of accurate time and the *dispensing* of accurate time. We shall take up each in order.

GETTING ACCURATE TIME

We accept the stars as our primary clocks or time keepers, considering as a "star day" (sidereal day) the difference in time between two successive passages of a star across the meridian, or north and south line, of our Observatory. Our problem now is to find out, to the smallest possible fraction of a second, the time a definite star crosses our meridian according to our own master clocks. But the *Nautical Almanac*, or *American Ephemeris*, gives tables allowing us to compute, correct to the thousandths of a second, just when a star should really cross our meridian. The difference between this value and the time of passage as given by our master clocks gives us our clock errors.

How do we check, however, our primary clock, the star, against our Observatory master clocks? Simultaneously, on a chronograph we record the seconds' beats of our master clock, and the time the star crosses the meridian. The chronograph has many forms, but in a simple, standard type, it consists of a drum with paper thereon, rotating constantly and uniformly, upon which a pen makes a continuous spiraling straight line except when interrupted by a kink exactly every second, produced by electrical connection with the master clock. So far for recording the clock; how about the star?

The passage of the star across the meridian is observed by a transit instrument. This is essentially a telescope which can be rotated, in the plane of the meridian, about a horizontal axis. It is set for the selected star. As this crosses the field of view either a key is tapped to make a kink in the chronograph record every time the star passes cross-hairs in the eyepiece, or else a movable crosshair is kept steadily on the moving star by turning a little wheel. As this wheel turns it repeatedly makes and breaks an electrical circuit, and thus kinks the recording line on the chronograph. Other newer methods for recording the star passage will be mentioned later.

This really sounds comparatively simple: star, transit, clock, chronograph. Can not these be easily coupled to give at least one-thousandths of a second accuracy? At present, the trouble in general is not so much with the master clocks or chronographs. It is with the transit. Let us examine this more closely.

Our old professor of physics at Hopkins, Dr. Pfund, used to say: "I will not be satisfied until you lose your respect for all the instruments in our laboratory!" By this he meant, that all instruments, like men, have limits of accuracy, and it was up to us to find that limit. So it is with the transit. It is all very well to say: All you have to do is to get your transit swinging in the meridian plane, and there you are! How do you know that the axis is really horizontal? How do