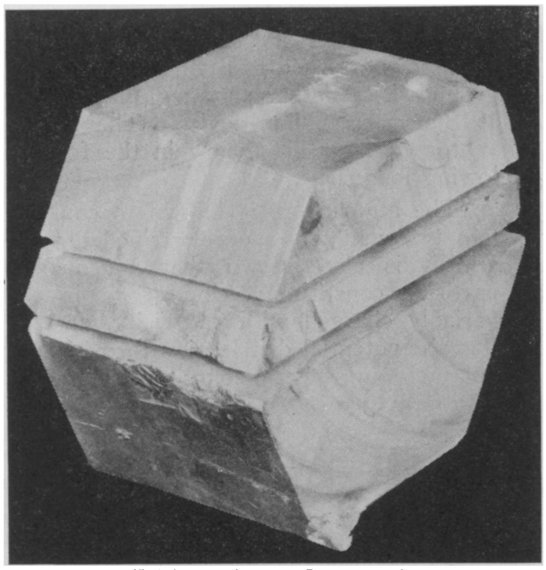
# Splitting Seconds
## With the World's Newest Clocks

*Astronomy*

By JAMES STOKLEY



**Vibrating Crystal**

**After the final cutting its 100,000 movements a second will help keep the latest clocks going.**

WHEN your watch keeps time to within a minute a week, you probably think it's doing pretty well.

And so it is—for a watch; but the astronomer, keeping track of the movements of the heavenly bodies, the seismologist, checking up the tremblings of the earth, and many another scientist, in laboratory and observatory, demand timekeeping of a much higher order of accuracy.

Accurate measurement of time became possible in 1673. In that year the Dutch astronomer and physicist, Christian Huygens, published his famous book, "Horologium Oscillatorium," which contained the first description of the pendulum clock.

Now an English inventor, after years of work, has perfected a clock that carries the pendulum clock close to what are probably the farthest limits of its accuracy. Still more recently, an American physicist, working in a great New York research laboratory, has perfected a totally new form of clock. It dispenses with the pendulum entirely, though it is comparable in accuracy with the best of the pendulum clocks of a few years ago. It is the most radical improvement that has been made in clockmaking since the time of Huygens himself.

### Differences in Standard Clocks

Laymen are often surprised when they see the clocks of an observatory to find that they may be as much as several seconds fast or slow. Even the standard clocks of the nation, in an underground vault at the Naval Observatory in Washington, are not exactly on the second. As a matter of fact, they do not tell the kind of time we use in our daily lives, but sidereal time, or star time.

Astronomers measure time from the motion of the stars across the field of a special form of telescope, arranged to move only from north to south. Our ordinary time is based on the sun. The year as measured by sun time contains one day less than the year measured by star time, which means that the solar day is about four minutes longer than the sidereal day.

At the time of the vernal equinox in March, sidereal time and solar time are the same. But then the sidereal clock seems to gain four minutes a day, until, by the autumnal equinox in September, it is exactly 12 hours ahead of the solar clock. By the following March the two are again even.

All this happens because the earth revolves around the sun at the same time that it is rotating on its axis. The yearly motion of the earth in its orbit causes the apparent movement of the sun among the stars during the year. Each day it is about one degree farther east among the stars than it was the day before, so if we take the time from a sidereal clock, it seems to come to the meridian about four minutes later.

But even the sidereal clocks in an observatory do not ordinarily show correct sidereal time. They may be a second or so fast or slow, and the astronomers in charge do not worry about it. What they are interested in is the rate. The clock may gain or lose a second or two a day, but does it gain or lose the same amount every day, year in and year out? If the amount it changes from day to day remains constant, then the astronomer always knows just how much to add or subtract from the time on the clock face to get the exact time.

Astronomical clocks are delicate affairs. They are kept in hermetically sealed cases, in vaults in which the temperature varies less than a degree between winter and summer. Naturally, any interference with them, to set them, would interfere with their delicate adjustments, so they are rarely touched. The winding is accomplished electrically.

The great Galileo, who lived from 1564 to 1642, is generally given credit for discovering the fact that a pendulum always takes the same time to swing, no matter whether it is swinging in a large arc or a short one. But it was the Dutchman, Huygens, who first applied the principle to a clock.

### Keeping the Pendulum Swinging

A freely swinging pendulum is the most accurate possible timekeeper. If it is kept at the same temperature, so that its length does not change, successive swings will be almost perfectly identical. But no matter how perfect the support, there is always some friction, so that no such pendulum will keep swinging indefinitely, not even if in a vacuum to prevent air friction.

Therefore, Huygens and all his successors have found it necessary to keep the pendulum going. In the ordinary clock this is done by an escapement which gives the pendulum a little push every second. This push introduces inaccuracies. If it were always made exactly at the moment the pendulum is hanging vertically in the middle of its swing, all would be well. But no mechanism is perfect, and sometimes the push comes too early or too late, making the pendulum swing either too rapidly or too slowly.

During the years from 1673 to the beginning of the present century, refinements were made on Huygens' original design. These culminated with the Riefler clock, a German product that is still the U. S. standard at the Naval Observatory in Washington, where three are in use. The Riefler clock will maintain a constant rate within about a hundredth of a second a day, a degree of accuracy far more than ample for most practical purposes and even adequate for much scientific work.

But the quest after increased precision is a never ending one on the part of the people who make scientific instruments, so an Englishman, W. H. Shortt, invented a clock that has inaugurated a new order of precise time. He considered the freely swinging pendulum, and wondered if it couldn't be applied in some way.

The ordinary clock pendulum has to release the mechanism that supplies it with energy to keep it going, and this robs it of energy, and introduces another source of inaccuracy. If the pendulum had nothing to do but swing, then an almost perfect timepiece would result. But a clock, to be of use, must have hands, and a dial. How is a freely swinging pendulum to operate the mechanism to turn the hands?

Then Mr. Shortt got a brilliant inspiration. Why not have two pendulums, one a master, that had nothing to do but swing, the other a slave, that did all the work of operating the mechanism?

### Slave Tells Time

He worked out a means of accomplishing this remarkable feat, and the present-day Synchronome clock is the result. The connections between the master and the slave pendulums are electric. The slave clock is itself a highly accurate electric timekeeper.

The free pendulum is mounted in a sealed case from which most of the air has been exhausted, and is started swinging when set up. Every 30 seconds the slave clock releases a tiny wheel which drops against a projection attached to the master pendulum. This provides just enough energy to keep it moving, but has hardly any appreciable effect on its accuracy.

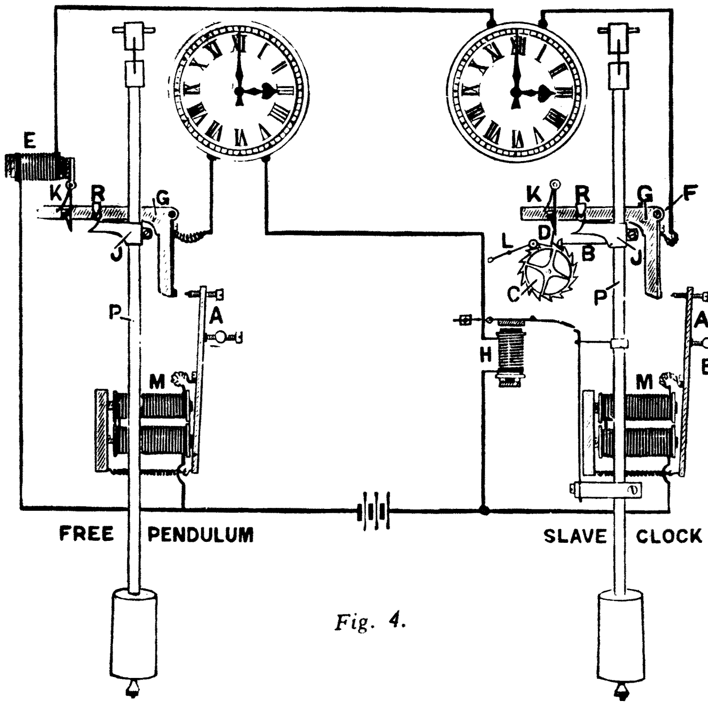



*Fig. 4.*

**The long-known principle of the pendulum is most accurately applied in the Shortt Synchronome clock. A free pendulum swings to keep time and a slave clock does the work of turning the hands.**

The slave pendulum is set to lose about six seconds a day, as compared with the master, so that it loses about 1/480 of a second every 30 seconds. Every time the little falling wheel supplies energy to the master pendulum, it operates a magnet near the slave pendulum. This pulls down a little lever, which comes near a small spring mounted on the slave pendulum itself. As long as the slave is a bit ahead of the master, the spring is not touched, but soon the slave falls a little behind the master. Then the lever falls and strikes against the spring; the slave pendulum is speeded up a bit and on the next swing is again ahead of the master.

The two pendulums never differ more than 1/240 of a second, from one end of the year to the other, so that, within this amount, the slave clock is always exactly in accord with the free pendulum.

Such clocks have been installed in various European observatories, and some in America, but the most elaborate installation is in a private laboratory near New York City. This is the Loomis Laboratory, at Tuxedo Park, owned by Alfred L. Loomis, a New York banker. Mr. Loomis has already turned out a number of important pieces of scientific work, though the laboratory has been in operation only a few years. He has three complete sets of slave clocks and masters, together with an elaborate automatic radio receiver with which he can receive time signals from all over the world.

In spite of the accurate development of the pendulum clock a few years from now even this may be passe. At the Bell Telephone Laboratories, in New York City, a young physicist, Dr. W. A. Marrison, has invented a totally new form of clock. For the first time since 1673, he has dispensed with the pendulum itself in a highly accurate timepiece.

Primarily Dr. Marrison has been interested in a standard of frequency, rather than of time, but as a by-product his work has produced a clock that, without a pendulum, keeps time of accuracy comparable with that kept by a Riefler. So far, the Synchronome has some advantages on the Marrison device in point of precision. However, the great superiority of Dr. Marrison's invention comes from the fact that, not using a pendulum, it does not require as stable a support as the Riefler or Synchronome clocks. The latter clocks must be kept on firm piers of brick or concrete, preferably in an underground chamber, away from vibration. The Marrison clock can be used in a tall office building, on board a ship, or even in an airplane if necessary, so that it will do the work of a chronometer, but with far greater precision.

The control of the Marrison clock is accomplished by a crystal of quartz. When an oscillating electric current is applied to two metal plates, between which is a quartz crystal of the proper size, the crystal starts vibrating. A single crystal, cut a certain size and shape, always vibrates at the same rate, when excited by an electric current oscillating at this rate.

If a current oscillating at a different frequency is applied to the plates, the crystal fails to vibrate. Such a crystal may be used to control an oscillating current, and as such finds practical application in radio. Many broadcasting stations are "crystal controlled," which means that such a crystal keeps them from deviating from the frequency, or wavelength, assigned by Uncle Sam.

As Dr. Marrison has set up the experimental apparatus in New York, three crystals are used, each vibrating a hundred thousand times a second. Each is enclosed in a padded case to keep the temperature constant, and covered with a bell jar to prevent changes in air pressure of humidity. Each crystal is connected with an oscillating circuit from vacuum tubes, which keeps them running.

Any crystal can be connected with the clock through the medium of an electrical circuit called a "submultiple generator." Thus from the crystal there comes a current oscillating exactly 100,000 times a second, which is fed into the submultiple generator. Out of this comes a current of one one-thousandth of the frequency, that is, oscillating a thousand times a second. The current operates a 1,000-cycle motor that is geared to the hands of the clock face. Already, over short runs, Dr. Marrison has found that the clock rate keeps within a hundreth of a second a day, about the same as that of the Riefler.

*Science News-Letter, August 23, 1930*

## "Ruins" of Nature

THE reported discovery of "ruins of a large stone city containing hundreds of buildings" about 100 miles from San Diego, has been investigated by Spencer L. Rogers, curator of anthropology of the San Diego Museum, who reported to Science Service that the stone "city" was built by nature, and not by prehistoric Indians.

The site with its irregular stone formations was once chosen by Indians as a convenient ready-made place for a habitation, Mr. Rogers found.

*Archaeology*

*Science News-Letter, August 23, 1930*

# Train Dispatchers With Shifting Eyes

*Medicine*

DISCOVERY of a new occupational disease among railway train dispatchers in America was made by the Industrial Health Conservancy Laboratories of Cincinnati according to information made public by Dr. Carey P. McCord.

Of a group of 165 dispatchers from seventeen different railroads examined, two-thirds were afflicted with an involuntary to and fro shifting of the eyes which is the characteristic symptom of nystagmus, as the new disease is called.

Until the present time, America has been regarded as free of this occupational menace, which has taken a great toll of mine workers in England since its discovery there. Its exact cause is not definitely known, some authorities attributing the disease to deficient illumination and others to the eye strain resulting from constant motion of the eyes following objects in motion, as the eye of a miner follows the point of his pick or the sewing machine operator watches her needle.

Explaining the appearance of the optical ailment among the train dispatchers, the fatigue theory has been forwarded as more logical and continued use of a train sheet blamed for the eye strain.

Reports from the U. S. Public Health Service of Washington state that previous to this time practically no evidence of nystagmus has been discovered in this country. The Illinois commission examined 500 pick men in the mines of that state but did not find a single victim. From this it was assumed that superior hygienic working conditions in the United States rendered the American laborer immune from the disease that was cutting into the ranks of English workmen, often incapacitating them for work in the prime of life.

Naturally strong eyes appear to be no guarantee against the inroads of nystagmus. Dr. J. W. Tudor Thomas of the Cardiff Royal Infirmary found from a study of five hundred cases of nystagmus among miners, that as many workers originally blest with normal vision had been afflicted with the disease as had workmen with defective eyesight.

Neurotic tendencies, alcoholism, and anemia are thought to be factors increasing the hazard of nystagmus. That the workers in coal mines are the most frequent sufferers further suggests that the absence of colors may in some mysterious way react unfavorably on the eyes.

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# Beautiful New Waterfalls in Africa

*Geography*

A SERIES of gorgeous waterfalls never before seen by a European and practically unknown to natives have been discovered in South Africa by Farquhar B. Macrae of the Northern Rhodesian Civil Service and described by him in a report to the Royal Geographical Society.

One of the falls is 200 feet in height, or 33 feet higher than the Niagara Falls, and rivals in beauty the Famous Victoria Falls which are about twenty miles distant. This fall is, however, only one of a series following each other in rapid succession so that the total effect is that of a much greater drop totalling 334 feet. They are known to the natives as the Chiengkwasi Falls and are on the Chunga River which empties into the Zambezi. It is on the Zambezi River that the Victoria Falls are located. In describing the Chiengkwasi, Mr. Macrae says:

"The main Chiengkwasi fall is a fine sight. Numerous very green ferns grow in holes and cracks in the stone and the water dashes down over the smooth face of the rock, spurting out into little plumes of spray wherever it meets an obstacle. In times of flood it must be an awe-inspiring sight during the few hours that such a short river would remain at its maximum height."

A few miles from the Chiengkwasi Mr. Macrae found another impressive series of five falls. The largest of these was a drop of 83 feet.

"Below this fall the scenery is most imposing," he continues, "Towering basalt precipices rise on either side of the river, which is never much more than 100 feet broad and is generally considerably narrower. At one point the cliffs cannot well be less than 400 feet high and are probably higher. They rise in one sheer wall from the water's edge. The general impression of height is greater than that conveyed to an observer standing at the bottom of the Palm Grove at the Victoria Falls."

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