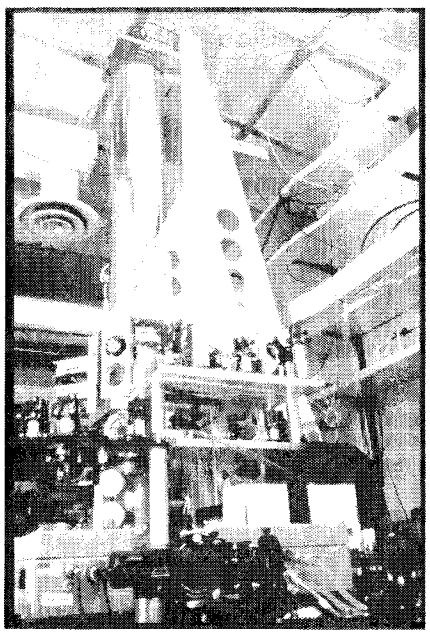
WHO USES PRECISION TIME?

Many of the nation's scientific and technological activities require this extreme precision. Major users of precise time and frequency include spacecraft tracking stations, civilian and military aircraft and ships (for navigational purposes), commercial and amateur radio and television broadcasters, seismographers, geophysicists, radio-astronomers, electrical power distribution networks, scientific laboratories and manufacturers of advanced technical products of all kinds.



NIST-F1 Fountain Clock

HOW TO RECEIVE ATOMIC TIME SIGNALS

There are many ways to utilize NIST's standard time and frequency. Users can receive time and frequency signals from our shortwave radio stations WWV and WWVH, operated in Colorado and Hawaii. Their time and frequency signals are heard over very wide areas by ships, planes, military bases, individual users, and scientific establishments. Broadcast accuracy is maintained by reference to the atomic clocks in Boulder. These time signals and voice announcements every minute may also be heard by dialing 303/499-7111 (a toll call from outside the Denver area). The announcements are made in Coordinated Universal Time (UTC).

WWVB, a 60-kHz (longwave) station also in Colorado, sends a powerful signal to clocks, watches, and electronic equipment all over North America, enabling them to automatically set themselves to the correct time.

NIST also provides time services via the Internet and via dialup modems for computer users, businesses, stock exchanges, and anyone else who needs reliable, accurate time information. Visit **www.time.gov** for details and to obtain free software for accessing these services.

Looking to the future, NIST's Time and Frequency Division is studying cooled, stored ion systems as potential standards with even higher performance, and is looking at new ways to use satellites to precisely synchronize widely separated clocks.

For more information on the time and frequency standards and services of NIST, contact the Time and Frequency Division, MS-847, National Institute of Standards and Technology, Boulder, Colorado 80305.

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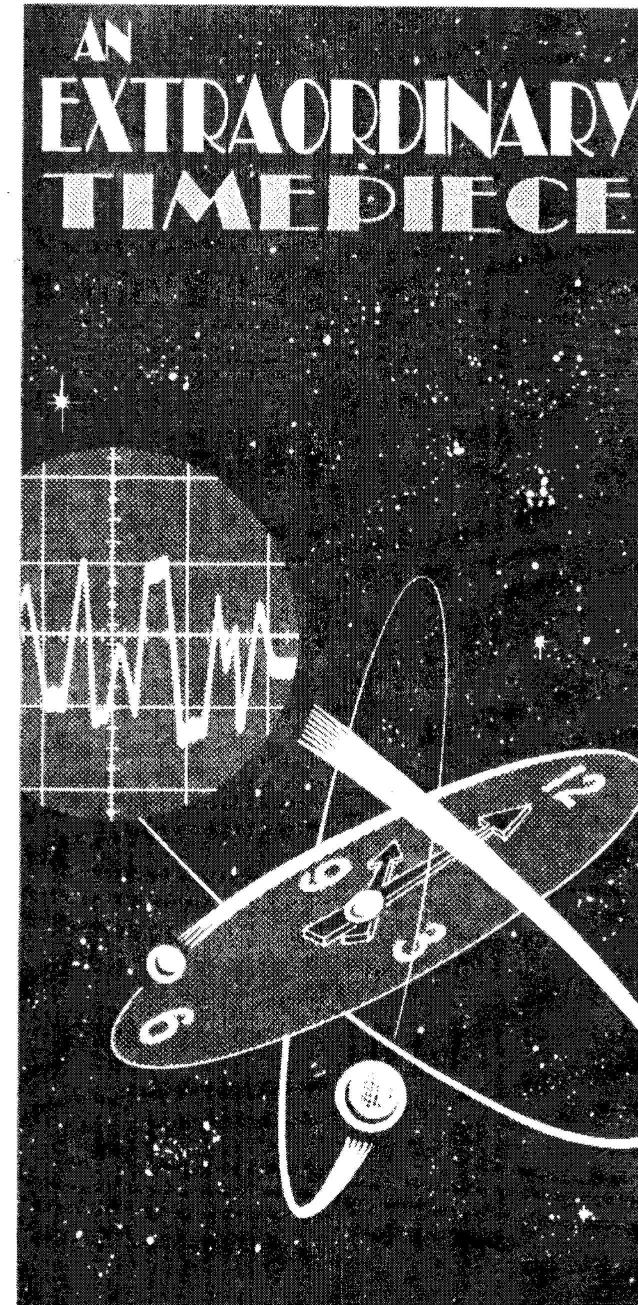
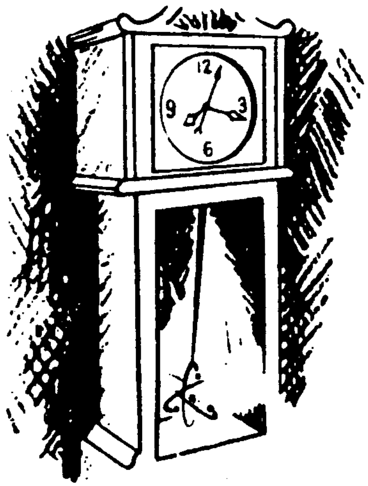
National Institute of Standards and Technology

Boulder, Colorado

The NIST Atomic Clock





With a "pendulum" consisting of atoms oscillating more than nine billion times a second, the NIST Atomic Clock measures time more accurately than we can measure any other quantity. Located in Boulder, Colorado, this unusual timepiece is operated by the National Institute of Standards and Technology, an agency of the Technology Administration, U.S. Department of Commerce.

Clocks, Time, and Frequency

In essence, a clock is simply a mechanism that counts and records a series of periodic events. Examples of such events are the swings of a pendulum, or the oscillations of an atom or molecule.

Time measurement is intimately tied to the frequency of these recurring events. The earth rotates on its axis at a frequency of once per day; it revolves about the sun at a frequency of once per year; the pendulum of a grandfather clock may swing back and forth every two seconds; and a wristwatch might tick five times per second. The NIST Atomic Clock is also based on a source of frequency, the frequency of cesium atoms. Cesium is a silvery metal that melts and flows like mercury just above room temperature.

Atomic Pendulum

Atomic-clock accuracy stems from the very constant resonance frequency of atoms. Since 1967, by international agreement, the second is defined as the duration of 9,192,631,770 oscillations of the undisturbed cesium atom. An atomic clock is a device designed to detect the oscillations while disturbing the atoms as little as possible. Electronic circuits in the clock count the oscillations and display the accumulating counts much as an ordinary clock counts and displays the swings of a pendulum. When 9,192,631,770 oscillations have occurred, the clock indicates that one second has passed. As the seconds pass, they are accumulated into minutes and hours, as in any other clock, except that the resulting atomic time scale is millions of times more uniform than a time scale determined by the earth's rotation around its axis. In fact, atomic clocks allow us to measure independently the tiny variations in the earth's rotation.

The Atomic Clock System

The NIST Atomic Clock system is comprised of three main elements: a primary frequency/time standard, a group of commercial atomic clocks and hydrogen masers, and the computing and measuring equipment that keeps track of the performance of all of them and permits them to be compared with one another.

In December 1999, a new primary standard called NIST-F1 was put into service. NIST-F1 is a fountain-type cesium standard that achieves remarkable performance. Where previous cesium beam devices used hot atoms fired at high speed through the apparatus, NIST-F1 uses cold atoms gently lofted vertically and allowed to fall back down, like a water fountain. This allows much more time to measure each atom's resonant frequency, and reduces the Doppler effect caused by high speeds. NIST-F1 does not operate all the time — it is used to calibrate and evaluate the performance of the secondary standards.

The secondary standards, about a dozen in all, run all the time. Having many of them adds statistical reliability to the timekeeping process. It also permits repairs and modifications without interrupting the time scales.

The third element, a combination of computers and measurement equipment, automatically monitors the frequencies or rates of all the clocks against each other, and measures the time differences between the individual clocks. Each clock's performance is evaluated and a weighted average of the inferred atomic time from each clock is computed.

The result is a continuous measure of atomic time, to be displayed on indicators in the laboratory and made available as radio-frequency signals and electronic "ticks." The system keeps time so accurately that it gains or loses only about one billionth of a second per week (equivalent to about one second in 20 million years).