A leap into 1978

by Collier Smith

The holiday season at NBS/Boulder always seems to arrive bearing glad tidings of another leap second. As early as October each year for the past 5 years the word has come from Paris that a leap second would be added on December 31. This year, as usual, the extra second will be added just before 5 p.m. MST (24:00 Coordinated Universal Time) on New Year's Eve. The leap second is inserted into Coordinated Universal Time (UTC) at the very end of 1977.

Leap seconds are needed to keep the world's clocks closely in step with the earth's spin, so that sunrise, noon and sunset continue to occur at reasonable times according to our clocks. Modern atomic clocks, the basis for worldwide timekeeping, are used because they are much more constant than the rotation of the earth. But they do keep time at a slightly different rate from that currently indicated by the sun. As a result, about once a year we have to make an adjustment to atomic time, and we call this a leap second. It is analogous to the extra day added during leap years to keep the calendar in step with the seasons.

Who decides when a leap second is needed? It is a cooperative effort among many astronomers who monitor the earth's spin by observing the stars and physicists who operate the very accurate atomic clocks. These efforts are scattered around the world and are coordinated through the International Time Bureau (BIH) in Paris. The BIH collects data from astronomical observatories and atomic clock laboratories in dozens of countries. They average the data continuously and when they see that the difference between clock time and astronomical time will soon exceed the allowed nine tenths of a second, they issue a call for another leap second. The first leap second occurred in June 1972, and the next in December that same year. Since then, one per year has been needed, always on December 31.

NBS is one of two government laboratories that provide references for most public time in the U.S. (The other is the U.S. Naval Observatory.) Also, since NBS is charged with keeping standards for the U.S., it must, by international agreement, keep its clocks coordinated with UTC within about one thousandth of a second.

"In actual practice, we do much better than that," says James Barnes, chief of the Time and Frequency Division. "We maintain agreement within a few millionths of a second."

The NBS atomic clock system includes nine separate clocks. Eight are small commercial cesium clocks and the other is a large primary standard built by NBS. There are only two other laboratories (in Canada and West Germany) which have similar operational primary cesium standards. The rest of the NBS clock system consists of instrumentation for comparing the various clocks with the primary standard and with each other and a computer for compiling weighted averages and analyzing the performance of all the clocks.

All these clocks run independently and from them several different time scales are derived: NBS Atomic Time, UTC(NBS) and local (Boulder) time.

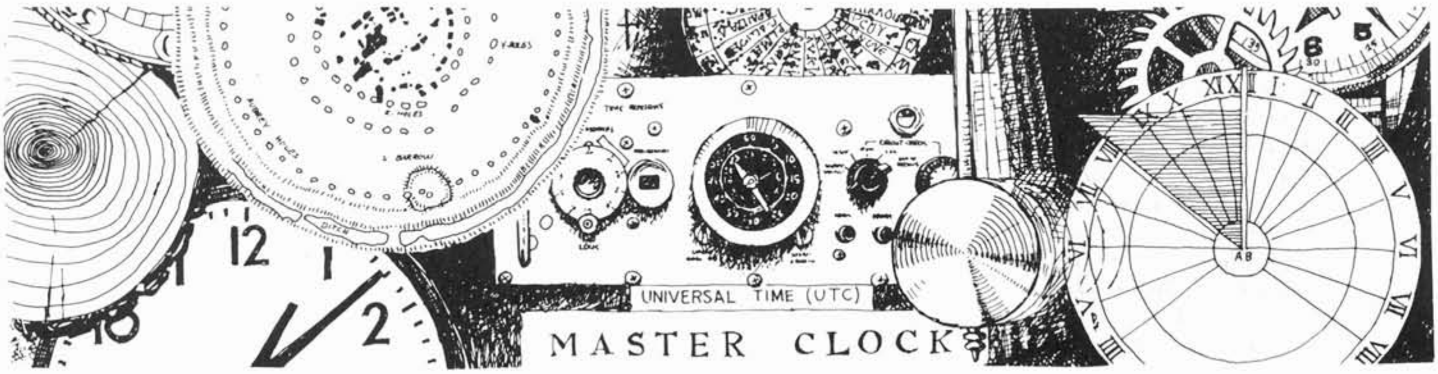
NBS Atomic Time is the time scale produced by the whole system. It is the basis for the other scales and never includes the leap second.

UTC(NBS) is derived from NBS Atomic Time by applying the necessary leap seconds and very small rate adjustments to maintain coordination with the rest of the world. The present difference between UTC(NBS) and NBS Atomic Time is about 16 seconds, because of the leap seconds and other adjustments that have been made since 1958 when NBS Atomic Time had its origin.

Local time (Boulder), in turn, is the same as UTC (NBS) except it is 6 or 7 hours behind, depending on whether daylight saving or standard time is in effect. "UTC grew out of the old Greenwich Mean Time and therefore today, the 7-hour difference between local time and UTC still reflects the difference in longitude between London (Greenwich) and the local time zone," explains Helmut Hellwig, who is in charge of the section which operates the standards.

How is the leap second actually inserted into the UTC time scale? A few hours in advance, the system is programmed to add the extra second to the UTC clock readouts. Then, just at the right moment, the computer delays the 00:00:00 reading on January 1, 1978, by one second. The effect is to make the last minute of UTC on December 31, 1977, one second longer. In Boulder, all this takes place at 5 p.m. MST.

The NBS time and frequency standard is the only U.S. primary standard located away from NBS headquarters in Gaithersburg and it is the only one accessible to the public more or less directly. Public access is provided through the NBS time and frequency dissemination services which furnish



radio, telephone and satellite signals and, on occasion, through direct clock comparisons in Boulder. NBS also has services involving national television networks to provide accurate time and frequency references to most of the country. All these are referenced, with various degrees of accuracy, to the basic standards in Boulder.

Several times a year, NBS compares its own clocks' readings with others scattered around the world. Several methods are used, to do this but the most accurate at present is to physically carry an atomic clock from Boulder to the other clock sites in Paris, at the Naval Observatory and elsewhere. Sometimes portable clocks from some of these laboratories are brought to Boulder. The portable atomic clock, while not as accurate as the primary standards in Boulder, is still good enough to transfer time with better than millionth-of-a-second accuracy on trips lasting a day or so in each direction.

Another method, nearly as good, involves the use of the low frequency radio waves of the Loran-C navigation system. In the future, satellites may be used either as relay points which pass on signals from the ground, or to actually carry the atomic clocks into orbit and broadcast their signals to earth. Such methods offer more reliability and accuracy than ground-to-ground transmissions and one satellite can cover up to 40 percent of the earth's surface at one time.

All this effort may seem like a lot of work just to tell time, but of course, there is more to the story than that. Most of the electronics and electrical power industries depend on NBS for accurate frequency standards. Many scientific endeavors, such as environmental and seismological sensing networks require accurate time-of-day information to label their data. Navigators need high-quality time information to determine position on the earth and oceans, in the air and in space. And the sophistication of most of these needs is growing yearly.

As Lewis Carroll's Red Queen observed in *Through the Looking-Glass,*". . .it takes all the running you can do, to keep in the same place."

"We have to keep running to stay ahead of the needs of industry and technology," says Barnes, "it wouldn't do to have NBS in the position of follower in this field."

So feel free to use the NBS clock to set your new holiday digital watch; atomic time may be a million times more accurate than *you* need, but someone out there appreciates it.

[For those who wish to take the above advice, NBS time (UTC) may be heard by dialing (303) 499-7111, a toll call outside the Boulder-Denver area.]

Howard Machlan and Helmut Hellwig (rear) install a working model of a late 17th century clock in a display near the NBS atomic clock system. Pendulum clocks of this type were considered excellent if they kept time to a minute a day, a far cry from the three millionths of a second per year achieved by the modern NBS system.

Physicist Dave Glaze was one of the principal builders of the latest NBS time and frequency standard NBS-6. He also worked on several of the preceding five generations of NBS atomic clocks.