ATOMIC CLOCKS: FIRST CLASS INTERNATIONAL TRAVELERS

What do you do if the passenger in the airplane seat next to you is a black box and is ticking? Chances are you should ask it the time; it is probably an atomic clock.

Atomic clocks use the vibrations of atoms as their "pendulum." Since the atomic vibration rate is very constant and relatively unaffected by outside influences, atomic time is incredibly accurate. It is about 100,000 times more accurate than the rotation of the earth as a timekeeping standard.

Atomic clocks get around a lot these days, what with synchronizing our spacecraft tracking stations and linking the time scales of large radio telescopes for studies of stellar radio emissions.

For many of these jobs, sophisticated atomic clocks are the only instruments with sufficient timing accuracy. Other methods have too much room for error.

Sometimes, however, it becomes necessary for the Bureau to know the difference between the American atomic time scale and the international atomic time scale maintained in Paris for this purpose. They buy a seat on a transatlantic jet and send a portable atomic clock on the trip, accompanied by a physicist to carry out the measurements and insure careful handling of the continuously running clock.

These comparisons are made every year or so to measure the difference between the NBS time and frequency standard and the time and frequency standard of the International Bureau of Time (BIH). Comparisons are necessary because the U.S. UTC (Universal Time Coordinated) scales, by international agreement, must be related accurately to the UTC (BIH) scale.

The most recent comparison, in September 1971, verified that the UTC (NBS) scale differed from the UTC (BIH) scale by less than 150 microseconds (millionths of a second). International agreement permits up to 1,000 microseconds difference. Even this small difference was virtually eliminated on January 1, 1972 when most UTC scales were adjusted slightly. The present difference is estimated to be less than 3 microseconds.

The BIH in Paris, France, is charged with generating an International Atomic Time scale (IAT) from the various time scales maintained in the participating countries. It maintains this scale as an international reference for comparison with all other scales, and as a base for generating the UTC (BIH) scale. All participating countries must then maintain their own UTC scales within 1/1000 of a second of UTC (BIH). Why must such a close tolerance be maintained? Primarily to avoid international ambiguities when specifying the exact time that events occur, especially scientific or astronomical events, and to permit international synchronization of clocks. If nations generate their own independent time scales with no provision for coordination, these scales will tend to diverge over the years, until, conceivably, 8 o'clock in the United States would coincide with half past 8 in Canada. Time scales diverge because clocks are not perfect, even atomic clocks. They all run at slightly different rates, and only by periodically resetting them can we maintain close agreement.

The UTC (BIH) scale, the standard of comparison for all the others, is controlled by reference to the BIH International Atomic Time scale (IAT). The IAT scale is a "paper" scale constructed by taking a weighted average of the atomic time scales of the participating countries. Seven laboratories, in the United States, England, Canada, France, Germany, and Switzerland, generate atomic time scales which are weighted and then used to generate the BIH IAT scale. UTC (BIH) is then adjusted to be an integral number of seconds different from IAT. (Currently, UTC (BIH) is 10 seconds later than IAT.)

Methods of comparing the various national scales and the BIH scale depend on the accuracy needed. Routine comparisons often employ radio transmissions such as LORAN-C. These transmissions are usually in the low to very-low frequency range to avoid some of the propagation errors that afflict high-frequency waves. More accurate comparisons require carrying portable atomic clocks from one laboratory to another. For instance, NBS can note the difference between a portable clock and the UTC (NBS) scale as maintained by the Time and Frequency Division in Boulder, Colo. Then the clock is put on an airplane (it occupies a seat in the first class section, where it can be plugged into the aircraft's power system) and flown to Paris. There, its reading is compared to the UTC (BIH) scale and the difference noted. Subtracting one difference from the other yields the difference between UTC (NBS) and UTC (BIH), and by calculation, the difference between NBS atomic time and BIH atomic time. Thus, the relations between the NBS scales and the BIH scales are established, and adjustments can be made to the UTC (NBS) scale, if necessary.

So, the next time you notice a ticking instrument strapped into the airliner seat next to you, and plugged into the wall, don't panic. Just ask it if the plane is on time. It will know.