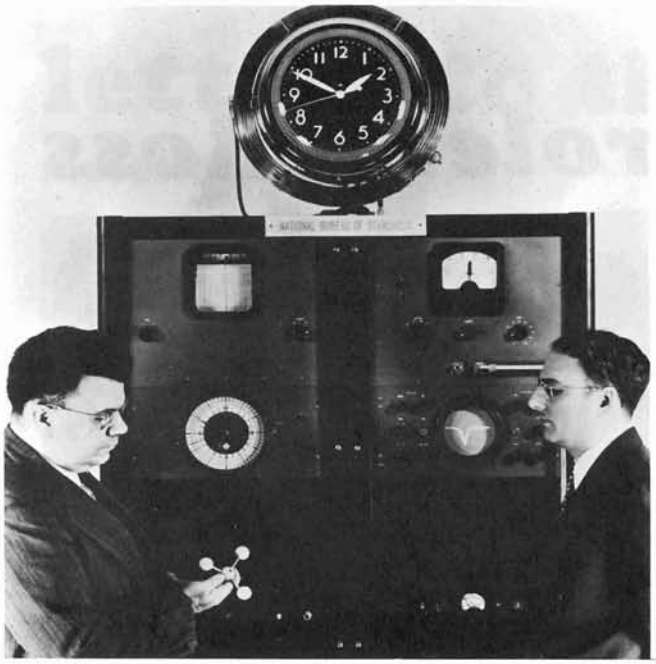


"...in 1949, the Bureau devised means for utilizing the vibrations of atoms in the ammonia molecule, derived from the microwave region of ammonia gas, to control an oscillator with which to drive a clock."

"The result was the first atomic clock ever built."

Measures for Progress
A History of the National Bureau of Standards

"A basically new, primary standard of frequency and time, invariant with age, has been developed at the National Bureau of Standards; an atomic clock based on a constant natural frequency associated with the vibration of the atoms in the ammonia molecule. Based on a principle developed by Dr. Harold Lyons of the Bureau's microwave research laboratory, the new clock promises to surpass by one or two orders of magnitude the accuracy of the present primary standard, the rotating earth. Dr. Lyons was assisted in the design and construction of the clock by B. F. Husten, E. D. Heberling and other members of his staff."

Technical News Bulletin
National Bureau of Standards
February, 1949

twenty-five years

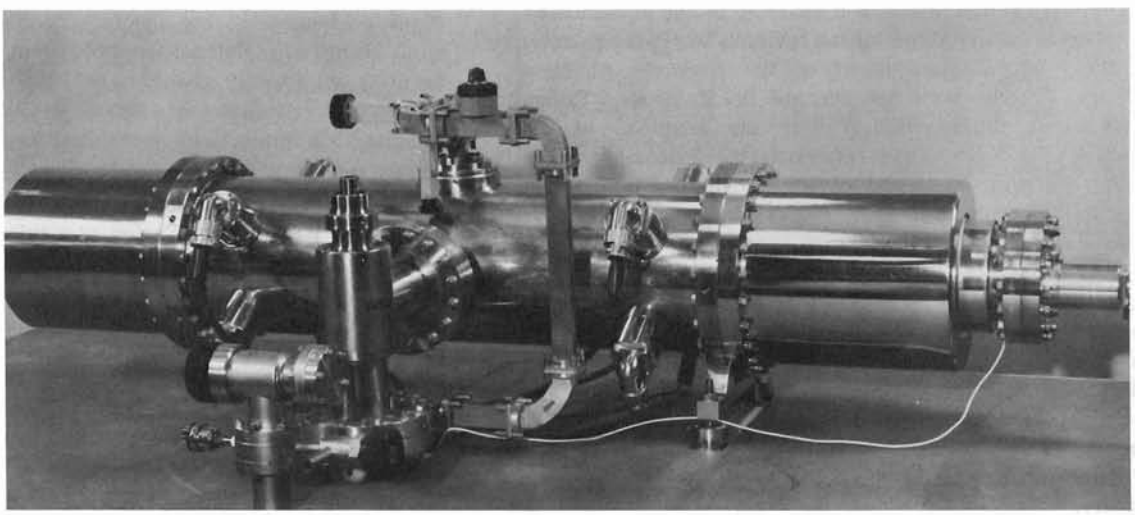
Thus, it was in 1949 that the swinging pendulum of a mechanical clock was replaced by the ammonia molecule as the new standard of frequency and time. This year, 1974, marks the twenty-fifth anniversary of the atomic timekeeping system.

The 1949 ammonia type clock resulted from the perfection of molecular and atomic physics techniques started in the 1920's. Although these techniques were in their infancy in 1920, physicists were striving to learn how matter interacted with electromagnetic energy (microwave, radar). The study of spectral lines, called spectroscopy, broadened. These distinct lines, the result of electromagnetic energy being absorbed or emitted by certain molecules and atoms at very precise frequencies, were discovered. The first atomic clock used the ammonia absorption line to regulate a frequency emitted from a quartz crystal oscillator. This frequency was in turn used to regulate two synchronous clocks, each set and compared to astronomical time. The quartz oscillator provided the clock's short-term stability, the ammonia absorption line the necessary long-term stability.

Refinement and application of new techniques by NBS and other world standards laboratories have established today's extremely accurate cesium beam standards. These standards provide a highly stable frequency, which in turn defines the world's unit of time interval, the second. Since 1967, the second of time has been internationally defined as "the duration of 9,192,631,770 periods of the radiation corresponding to the transition between two hyperfine levels of the ground state of the cesium 133 atom."

NBS atomic clocks are direct contributors to our world's uniform time, Coordinated Universal Time (UTC), maintained by the Bureau International de l'Heure (BIH) in Paris, France.

atomic timekeeping



NBS-4

later... tick ... tick ... tick

The NBS atomic clock system comprises three main elements; the frequency standard, a group of secondary atomic clocks, and the computing/measuring equipment. The frequency standard detects the frequency of the cesium atoms. This instrument is the primary standard of frequency for the nation and also "regulates" the NBS clock system. Continuous operation is neither necessary nor economical. Instead, it is turned on occasionally to calibrate the group of eight secondary frequency standards operating as clocks.

These clocks run continuously and form the second part of the system. These secondary frequency standards serve as "flywheels" to continue keeping time between calibrations.

The third element, a combination of computers and measurement equipment, occasionally compares the frequency of the primary standard to the frequencies or rates of the secondary clocks, and daily 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 provides NBS with 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 NBS Time and Frequency Division in Boulder maintains two of the world's most accurate frequency standards. Referred to as NBS-4 and NBS-5, the cesium beam devices were completed within the past two years.

Chronology of NBS Atomic Beam Devices

1949 NBS introduced to the world the first timepiece linked to an atomic device. During the same year, NBS started development of a cesium beam device.

1952 NBS-I, the first cesium standard of NBS became functional.

1954 NBS-I was disassembled and sent to the Boulder Colorado Laboratories.

1958 NBS-II, another cesium beam device was completed at the Boulder Laboratories.

1960 NBS-II was adopted as the NBS primary frequency reference.

1963 NBS-III was completed at Boulder, replacing NBS-II as the NBS primary frequency standard. NBS-III served as this standard until 1969.

1972 NBS-5, an advanced cesium beam device was completed as the Boulder Laboratories. Evaluation showed this device to be one of the world's most accurate atomic frequency standards.

1973 NBS-4, a different, advanced cesium device, was completed at Boulder. Both, NBS-4 and NBS-5 presently serve in a complementary way to calibrate the working NBS atomic clock system.

Time marches on... from an Egyptian water bowl to atomic timekeeping. This exhibit tracing the development of man's means of measuring time is currently on display at the Boulder Labs.

Since 1960, several generations of NBS cesium beam devices have provided our nation and NBS with a primary frequency standard. NBS-II, successor of the experimental device NBS-I, furnished this standard from 1960 until 1963, being replaced by NBS-III, which was used until 1969. NBS-5 became the latest generation of NBS cesium atom primary frequency standards in 1972. NBS-4, although initially completed in 1970, has been revised and is presently used as an independent primary frequency standard.

Forming a system which is mutually supportive, NBS-4 and NBS-5 provide accuracies approximately 100,000 times better than the second of time as measured by our revolving earth. If NBS-5 was allowed to run constantly for one million years without adjustment, it would still be accurate to better than ten seconds!

Future primary frequency sources may someday replace these cesium beam standards, as cesium devices replaced the ammonia molecular clock, but the concept of atomic clocks will continue.

A special celebration, in honor of the silver anniversary of the development of the world's first atomic clock by NBS, will be held at the Boulder Laboratories on Friday, February 22, 1974.

Guest speakers will include Dr. Betsy Ancker-Johnson, Assistant Secretary of Commerce for Science and Technology; Dr. Richard W. Roberts, NBS Director; Dr. James A. Barnes, Chief of the Time and Frequency Division; Dr. Edward U. Condon, Director of NBS twenty-five years ago, and Dr. Harold Lyons, who developed the first atomic timepiece. Other celebration participants include Charles Sawyer, who, as Secretary of Commerce in 1949, announced the development of the first atomic clock, and Bascom Birmingham, Deputy Director of IBS functions at Boulder.