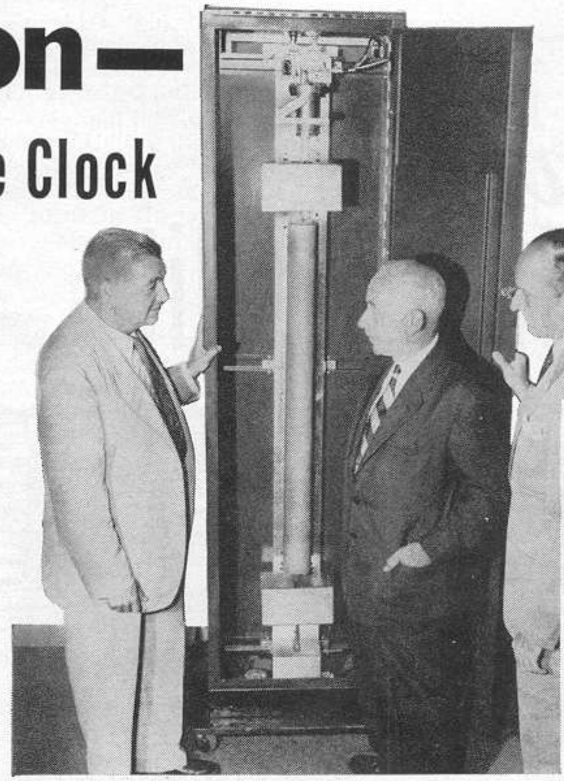
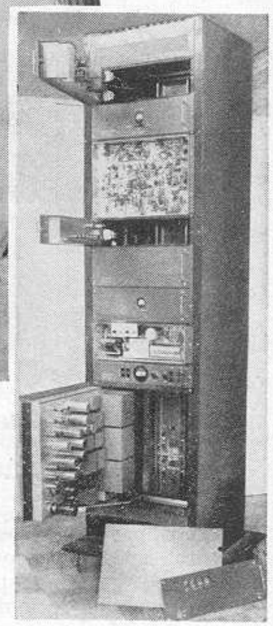
Atomichron—

World's Most Accurate Clock



Dr. J. R. Zacharias (left), a key figure in development of the Atomichron, H. C. Guterman (center), and J. H. Quick (right), chairman and president of National Company, view the atomic beam tube.



Front view of the Atomichron, which stands 7 feet high and weighs about 500 pounds. Unit costs $50,000.

First practical atomic primary frequency standard with stability better than 0.5 second in 300 years.

THE ATOMICHRON, a multi-purpose frequency producing instrument, was unveiled recently by *National Co., Inc.*, of Malden, Mass. The most accurate clock in the world, the Atomichron is the first atomic beam clock available for commercial use. By maintaining synchronism with the natural resonant frequency of the cesium atom, the device is the most accurate primary frequency standard in the world, it was said.

The extreme stability will permit: increased speed and volume of long distance telephone communications in higher frequencies of the spectrum; greater volume of industrial communications; extension of power and pipe line control systems; and increased accuracy in electronic navigational equipment. In the high frequency spectrum, the Atomichron will permit the use of radio receivers and transmitting equipment of unprecedented narrow bandwidths and precise frequency control, eliminating crowded air waves often resulting in one station or channel interfering with another. In the area of navigation, the device is being used by the Air Force in its experimental long-range "Navarho" navigation system.

How It Works

Electrons, and most sub-atomic particles, act in many respects like tiny bar magnets. The outer electron in an atom, like cesium, finds itself in the magnetic field of the nuclear magnet and tends to align itself just like a compass needle. If the electron is disturbed, it will vibrate about its position like the needle. Frequency of the vibration of the analogous compass needle is determined by the magnet strength of the needle, the field in which it is located, its weight, and shape. Corresponding quantities for the electron are fixed, unchanging, and identical for all electrons and cesium nuclei. It is the quality of not changing which makes the vibration frequency a primary standard and the Atomichron constantly corrects an auxiliary vacuum-tube oscillator to operate at the frequency of this electron resonance. (See diagram at right.)

A reservoir of cesium atoms is placed at one end of a long, evacuated chamber. As heat is applied, individual cesium atoms drift away from the pool. In the diagram, two cesium atoms of different orientations of nucleus and electron are considered to be given off and to begin drifting through the atomic beam tube, where they come under the influence of two permanent magnets and an r.f. field. The orientation of nucleus and electron in atom #2 is such that it is attracted to the strong pole of the first magnet, and deflected away from the r.f. chamber. Atom #1 exists in an energy state which causes it to be deflected away from the magnet and toward the r.f. chamber.

When the r.f. field is near the cesium resonance frequency, atom #1 will probably emit a photon and change its energy state to the configuration of atom #2. If the r.f. field is not near cesium resonance, the atom will probably remain at its original energy level.

As the atom passes through the second magnetic field, and if its energy state is unchanged, it is deflected away from the strong pole of the second magnet. If it has changed its energy state in the r.f. field, it is deflected toward the strong pole. In this case, however, deflection toward the strong

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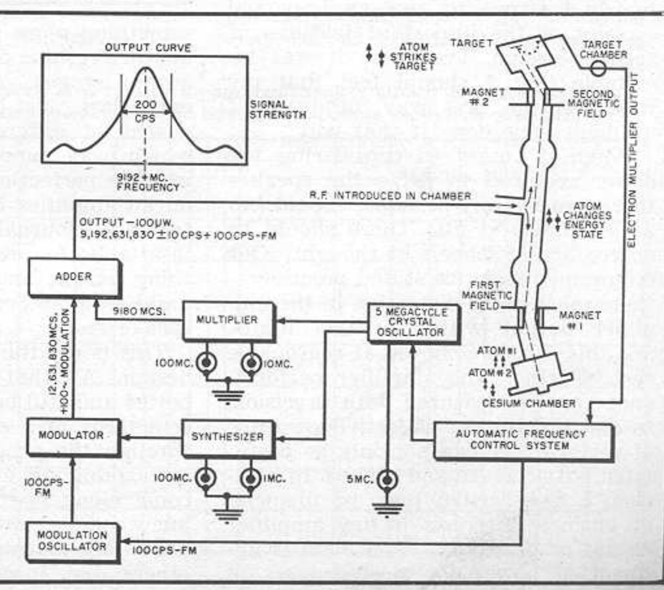

Functional block diagram of Atomichron showing the method of connecting the atomic beam tube into the system. The output curve shown here represents a device with a "Q" of almost 50 million.

Atomichron
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pole has the effect of conducting the atom into a sensing chamber and to a target.

The atom strikes the target, is ionized, and is attracted to the cathode of an electron multiplier, which amplifies the cesium input current a million times. The electron multiplier output current varies with the number and rapidity of impingements of ionized cesium atoms on the cathode. As the frequency of the r.f. field varies, the impingements on the cathode decrease, causing a change in the magnitude of the electron multiplier output current. This effect is used as the first step in adjusting the frequency of the r.f. signal to return it automatically to the standard value.

The frequency of the r.f. signal which is applied to the atomic beam tube is derived from a 5 mc. crystal oscillator. The output is multiplied to 9180 mc. Meanwhile, a synthesizer combines harmonics and subharmonics of the output of the basic 5 mc. oscillator in such a manner that when the synthesizer output is combined with the multiplier output in the adder, an output frequency is produced that is the nominal resonance frequency of cesium—9192.631830 mc. The cesium resonance frequency signal is also phase modulated by the 100 cps output of the modulation oscillator. The purpose of this modulation is to provide a determination of the direction of variation whenever the output of the crystal oscillator drifts.

The atomic beam output signal is amplified for transmission to one winding of a two-phase motor. The current applied to this winding by the feedback amplification system is automatically and continuously compared by the motor to the current supplied directly to the other winding of the motor by the 100 cps modulation oscillator. If the r.f. frequency is above cesium resonance, the motor will operate in a direction which reduces the original error. If it is below resonance, the motor turns in the opposite direction. This rotation is then transmitted through a gear box to a variable capacitor which adjusts the output of the 5 mc. crystal oscillator to bring the frequency at the atomic beam back to standard.

Since the crystal oscillator is under continuous surveillance for precision, the basic output is a 5 mc. signal stable and reproducible to 1 part in 10^{11}. Higher frequencies are taken from the multiplier and sub-multiples are taken from the synthesizer as shown in the diagram.

Because of its relatively small size and mobility, the Atomichron now makes high precision time interval and frequency control practical for navigation, communications, and engineering systems without reliance on radio time signals. —30—