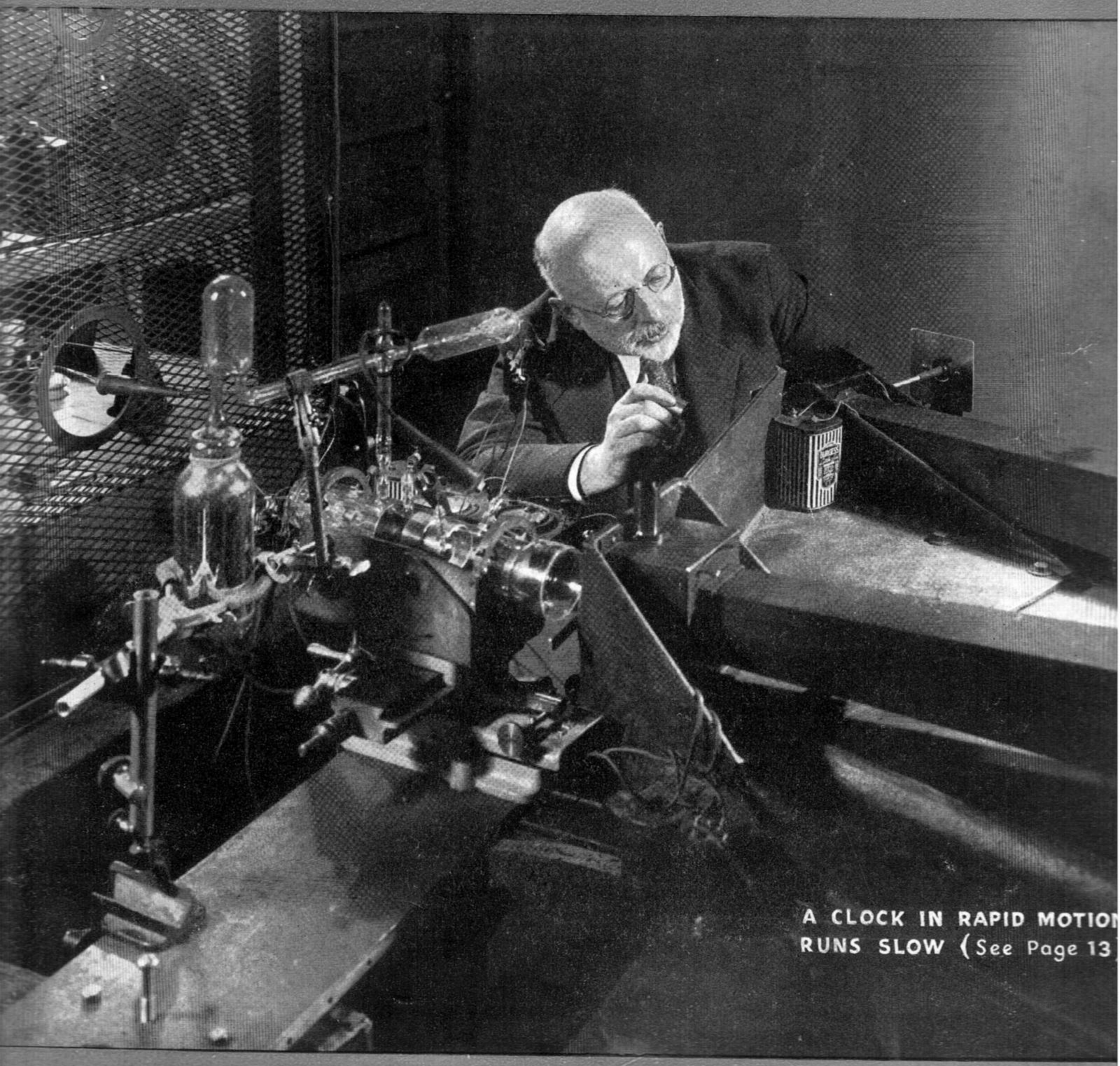
electronics

radio, communication, industrial applications of electron tubes . . . engineering and manufacture



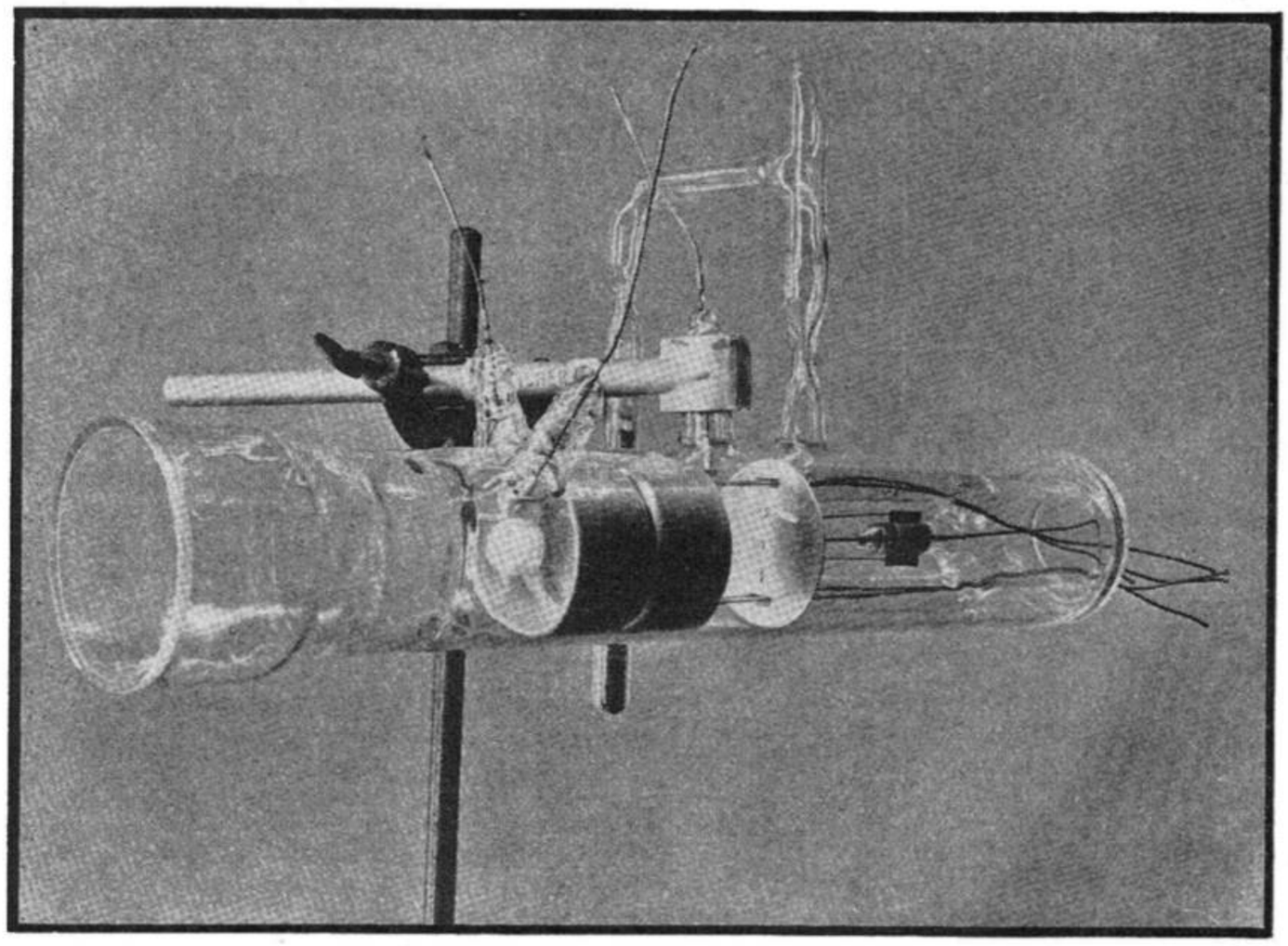
A CLOCK IN RAPID MOTION
RUNS SLOW (See Page 13

McGRAW-HILL

JUNE

The Ether—Fact or Fiction?

Dr. Herbert E. Ives of the Bell Laboratories, experimenting with the spectra produced by high-speed hydrogen ions, uncovers new evidence in the ether controversy, revives the possibility that the ether may be a reality after all



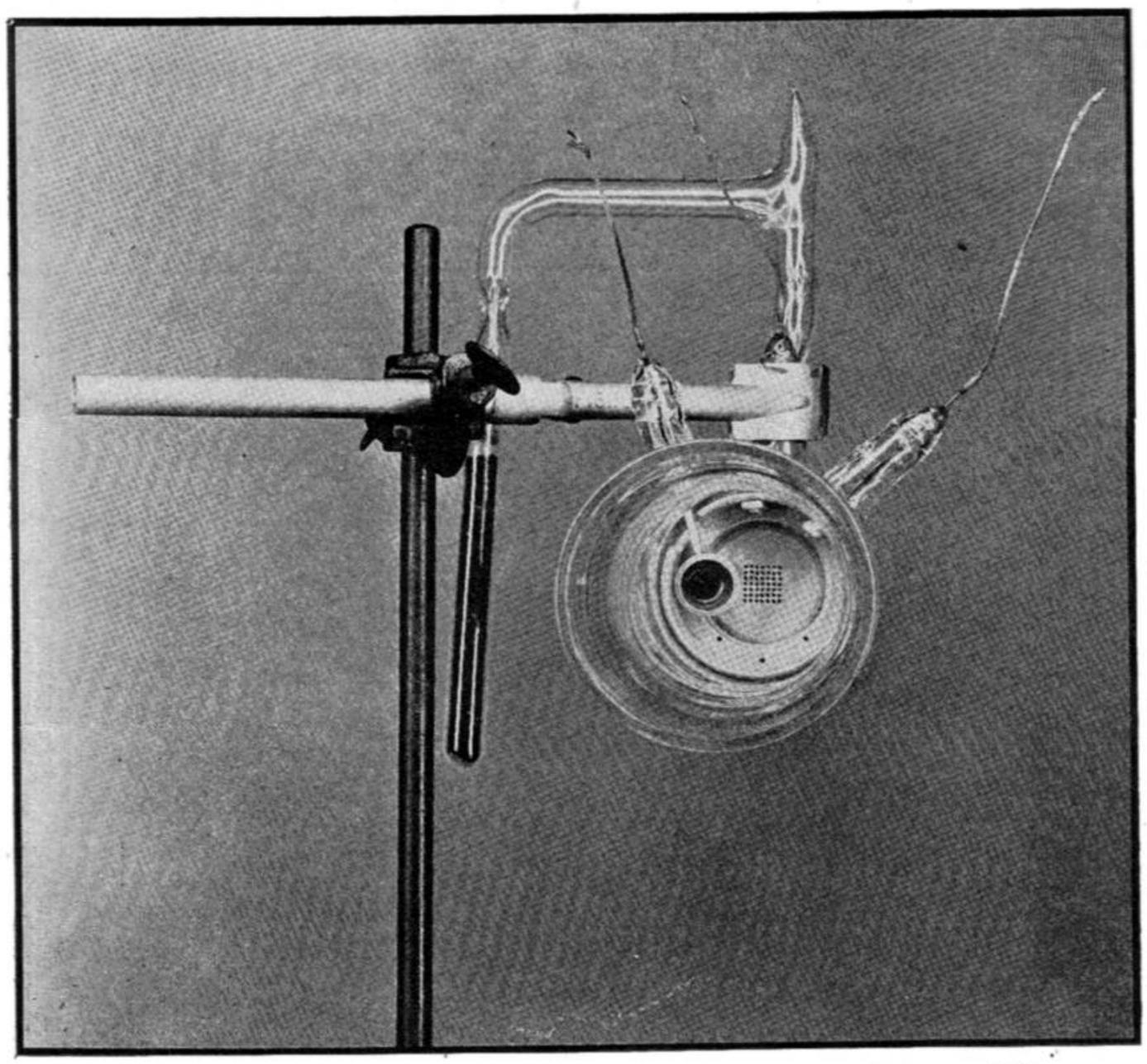
Electronic technique applied to pure research: canal-ray tube used by Dr. Ives in proving that a moving clock runs slow

THE question whether the ether, that strange medium in which radio waves and other forms of radiant energy are supposed to travel, is a fact or a fancy has been dormant for many years. Mathematical physicists have argued that the ether is a fiction, pure and simple. The engineer, whenever called upon to explain the passage of energy through space, usually makes use of the ether because it is a convenient device, and because no other explanation can be said to have any engineering significance.

Now comes word that the question of the ether's existence has been raised again, this time by the physicists. The occasion was the paper delivered by Dr. Herbert E. Ives of the Bell Laboratories, before the National Academy of Sciences on April 25th. In brief, what Dr. Ives reported was this: that hydrogen ions moving at high speeds produce light of longer wavelength than ions at rest. Stated differently, since wavelength and frequency are inversely proportional, the radiant energy produced by high-speed ions has a lower frequency than that produced by stationary ions. Now the frequency of the light radiated by ions has long been accepted as a standard of time. Hence if the mere fact of motion reduces the frequency produced by the ion, that is, if a moving clock runs slow compared with a stationary one, it may be argued that time is relative. The difference in clock rate is extremely small unless the speed of the ions is an appreciable fraction of the speed of light.

The existence of this "slowing down" effect had been predicted on theoretical grounds some 25 or 30 years before Dr. Ives succeeded in proving it. The story goes back to the famous "ether-drift" experiments of Michelson and Morley. Michelson and Morley set up elaborate equipment for measuring the speed of light to a very fine degree of precision. They measured the speed of two light beams, one traveling along the line of the earth's rotation around the sun, the other at right angles to this line. They found that the speed of both beams was, within the narrow limits of their experimental error, the same. This was an extremely interesting result. For the light was assumed to be traveling in the ether, and the ether was thought to pervade all space. If the ether is stationary in space then the earth drifts through it, and the speed of light traveling in the direction of the earth's motion should be slower than the speed of light traveling at right angles to the earth's motion. Since the two speeds were observed to be the same, the inference was that the ether moves with the earth. This seemed to be extremely unlikely, since if the ether moves with the earth it must be moving past all other celestial objects, and there was no reason to single out the earth for the honor of a stationary ether.

Two alternatives presented themselves. The first was to do away with the ether altogether. This answer to the problem had two points in its favor: First, Michelson and Morley had discovered no evidence of ether drift, and second, the ether itself was a very cumbersome medium to imagine. Experiments with ordinary elastic media had shown that the speed of waves through the medium depends on the square root of the elasticity of the medium divided by its density. The speed of the waves in ether, (the speed of light) is about 3×10^{10} cm./sec. The medium is obviously very rarified, since it cannot be detected, and its density must therefore be low. The rigidity of the material must therefore be correspondingly very great, many more times rigid than the hardest tool steel. That such a rigid medium could exist without giving



View of the tube structure through the observation window. Note perforations in plate and mirror which reflects light to window

many evidences of its presence seemed hard to imagine. So it was convenient to do away with it altogether.

But this was not the only possibility. An ingenious Irishman by the name of Fitzgerald suggested that the total lack of evidence of ether drift might be explained by inherent defects in the measuring tools employed by Michelson and Morley. In measuring the speed of light, it was necessary to measure distance and time, the quotient of the two being the velocity measured. If the length of the measuring rod decreased when it was lined up along the direction of the earth's motion, and if the clock used to measure time slowed down when it was moving in that direction, then any change in the speed of light would be offest by the changes in the measuring instruments, and no ether drift could be detected. Working from the value of ether drift to be expected, the percentage contraction of the measuring rod should be

$$\sqrt{1 - \frac{v^2}{c^2}}$$

where v is the velocity of the apparatus and c is the velocity of light. Likewise the percentage slowing down of the clock rate should be the same.

Many attempts to verify experimentally these contractions in length and clock-rate have been made. Dayton C. Miller of the Case School of Applied Science reported small positive effects in a repetition of the Michelson-Morley experiment which would suggest that the contraction was smaller than that indicated by the expression above, but other experimenters have repeated the null result. So the Fitzgerald contraction, and its more detailed embodiment in the Lorentz-Larmor theory of optics, have remained without positive proof. If we assume an all-pervading ether stationary in space, then the Michelson-Morley results prove the Fitzgerald contraction, but only in a negative way. A positive proof seems to be forthcoming from Dr. Ives' work.

Details of Dr. Ives' Experimental Equipment

The equipment used by Dr. Ives is an object lesson in the application of modern electronic technique to the problems of pure science. A brief description of the equipment follows.*

The heart of the apparatus is a specialized type of canal-ray (positive ion ray) tube, patterned after a design of A. J. Dempster, of the University of Chicago. The tube, shown in the illustration, contains an oxide-coated filament, and two perforated plates, the latter being separated from each other by about 1.5 mm. Between the filament and the first plate is applied a voltage of about 100 volts. Hydrogen gas, introduced to the tube from a side chamber containing charcoal in which the gas is adsorbed, is ionized by the potential gradient between the filament and plate. A large supply of hydrogen ions (consisting of two or three ionized atoms each) is thereby made available. By applying a very high voltage (up to 30,000 volts) between the first and second plates, the ions pass through the accurately aligned perforations and emerge as beams of high speed ions. These beams, usually called canal rays, are directed toward the observation end of the tube. The ions, in returning to their normal atomic state, go through definite energy transitions, and in this process give off light of several different wavelengths. The wavelength of 4861 Angstom units, a visible line in the hydrogen spectrum, was chosen as the basis of the study.

Outside the tube and adjacent to the observation window, an optical spectrograph was set up to analyze the light produced by the ions into its component spectrum colors. The spectrograph consists of a fine metal-on-glass grating, containing some 15,000 parallel ruled lines to the inch. The spectrum produced by this grating was focused on a photographic plate and recorded. The relative position of the spectrum lines on the plate indicates their relative wavelength, and any displacement of the lines toward the red end of the spectrum shows a decrease in the frequency of the light.

The experiment was difficult principally for the reason that the change in wavelength looked for was extremely small. The ions were accelerated by the high voltage to a speed about 0.005 the speed of light, and at this comparatively low speed, the change in wavelength is less than 0.05 Angstrom unit, necessitating a measuring accuracy of about 0.01 Angstrom unit. This is very high accuracy, even for spectroscopic work. It represents measurements

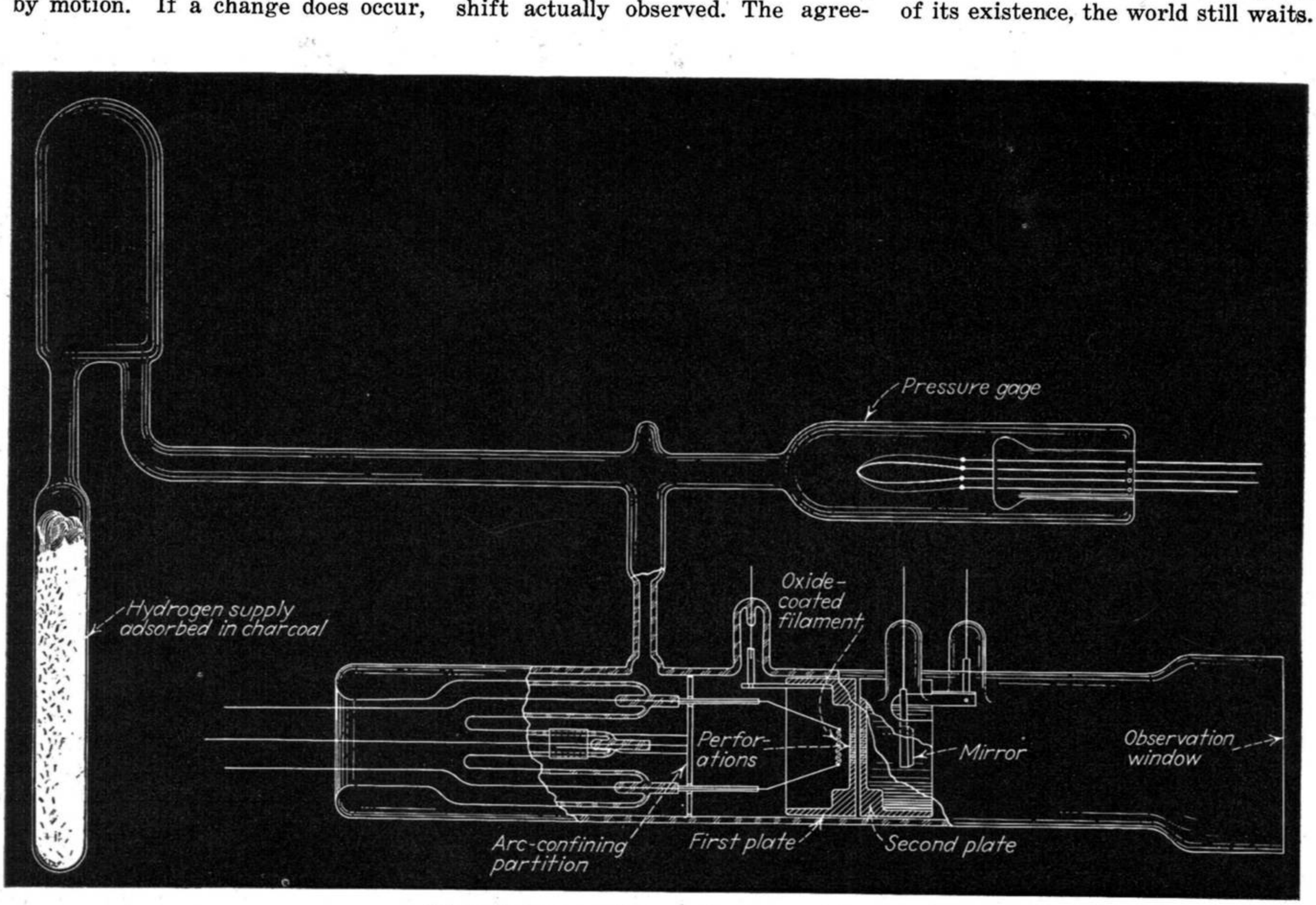
* Dr. Ives paper, containing complete details, is to appear in July issue of the *Journal of the Optical Society of America.*

of length of about a ten thousandth of a millionth of a centimeter.

To make comparisons of the wavelengths produced by high speed particles with those of stationary ones, it has been suggested that the effect be measured by noting the wave lengths of the light from ions moving laterally past the spectrograph as compared with that from the stationary ions always present in the tube. This is a very difficult, if not impossible, experimental procedure, and has been avoided in Dr. Ives' squipment by the use of a mirror, which reflects light to the spectrograph, the light being produced by ions which are apparently moving away from the spectrograph. The mirror used is within, and slightly off the main axis of the tube. The apparatus is thus capable of measuring wavelengths produced by ions moving about 1000 miles a second *toward* the spectrograph, and at the same time by the use of the mirror, of ions moving at the same speed *away from* the spectrograph. The average wavelength of the two measurements would correspond to the wavelength produced by an ion at rest if no change in frequency was produced by motion. If a change does occur, the average wavelength will differ from that due to the stationary ions.

The first experiments were tried with fast photographic plates, the exposure time being about one hour. During these tests, the entire apparatus (which is mounted on a massive rotatable steel platform) was rotated so that direction of the beam was successively to the east, north, west, and south. These results showed that the orientation of the instrument had no effect on the wavelengths, as was to be expected from theory. The final measurements were then made with much slower photographic plates, capable of revealing the position of the spectrum lines with much greater accuracy but requiring exposures of some 10 to 12 hours. Voltages of from 6800 to 18,400 were applied to the anodes, and kept constant to an accuracy of one-tenth of one per cent by an electrostatic voltmeter and an optical-beam indicating system. The voltage used is proportional to the square of the velocity attained by the ions, so the velocity attained can be computed, and the amount of wavelength shift to be expected therefrom can be compared with the shift actually observed. The agreement is remarkably close. Close enough in fact to give a positive support of the shift predicted by Lorentz and Lamor, which in turn is based on the Fitzgerald contraction of distance- and time-measuring equipment.

The conclusion is that the long-suspected conspiracy of nature against detection of ether drift is indeed a fact. Thus Michelson and Morley, in finding no ether drift, did not disprove the existence of the ether. Rather they proved the existence of the conspiracy. The question of the ether is still an open one. On the one hand the phenomena of interference, so evident in directional antenna design, seem to demand a wave motion as the basis of radiant energy propagation, and a wave motion demands a medium. This is strong evidence in favor of an ether. On the other hand, the medium must behave very differently from any ordinary elastic medium, to satisfy the simultaneous requirements of density and elasticity required to achieve the observed speed of propagation. The odds at the present betting, seem about 11-to-9 in favor of the ether. For a real proof of its existence, the world still waits.



Schematic diagram of the positive-ion ray tube