

struction of an eight-dish array at the Owens Valley Observatory be accepted.

- construction of a fully steerable 134-meter radome-enclosed dish be begun immediately, probably in the dry southwestern portion of the US.

- construction of the Very Large Array of 27 antennas, as proposed by the National Radio Astronomy Obser-

vatory, be begun immediately. This array would produce up to three pictures daily with a resolution of 1 sec of arc, which is equal to that of optical photographs.

- studies of methods for construction of very large steerable dishes be continued. Emphasis should be on design of an antenna useful at wavelengths as small as 3–6 mm.

- support of university radio astronomy be continued and improved.

- grants and contracts for US support of radio-astronomy installations require not only that half the observing time be available to visitors, but also that the installations be managed to assure representation of national interests and maximal usefulness to visitors.

## Measuring It Better: A Visit to Bureau International des Poids et Mesures

In an old house in Paris  
All covered with vines  
Lived twelve little girls  
In two straight lines.

If you drive west from Paris toward Versailles, you can easily pass through the little town of Sèvres without knowing that in it is the International Bureau of Weights and Measures. Only when you turn through a narrow arched gateway and climb a few hundred yards through the woods to a small clearing in the Parc de St Cloud do you come to the little historic manor, Pavillon de Breteuil.

The approach and the exterior suggest an atmosphere like that of the lines that open Ludwig Bemelmans's "Madeleine in Paris." Once, in fact, it had such an atmosphere. "Forty years ago," Jean Terrien, the present director told me on a recent visit, "Bureau International des Poids et Mesures had the feeling of an old lady. There were few pieces of original research."

Step inside, though, and you find a different atmosphere. The neat laboratories are making some of the most careful measurements in the world. The aim is to determine standard values and best procedures to measure them. Major concerns are length, mass, time, acceleration of gravity, electrical units, temperature, photometry and ionizing radiation.

The main function of the bureau is coordination of efforts everywhere to define and measure quantities accurately. Its small staff ("about 50 persons including the gardener," said Terrien) can not do such amounts of work as go on at the US National Bureau of Standards and the UK National Physical Laboratory. But it does much to test and compare the methods suggested by these and similar national laboratories. Moreover seven international consultative committees based at BIPM make the most fundamental decisions required for coordination and cooperation. Their seven

subjects are electrical quantities, photometry, thermometry, ionizing radiation, definition of the meter, definition of the second, definition of units.

40 governments have signed the "Convention du Mètre," the 1875 treaty under which BIPM was born. They meet at least every six years and usually every four years in the Conférence Générale des Poids et Mesures. (Terrien shuddered at the thought that BIPM might have become part of the League of Nations or the United Nations. As an organization fulfilling a purpose, it is running more effectively than those trying to find purposes they can fulfill.) The 40 elect an 18-member committee, which operates BIPM and the seven consultative committees.

The bureau is in no sense French although it happens to have a French home and a French director. Former directors have been Swiss, Italian, Norwegian and British. It does not even function as a standards bureau



**HISTORIC MANOR HOUSE** in western outskirts of Paris is home for international bureau that specializes in standard values and best procedures to measure them.

**DIRECTOR JEAN TERRIEN** was formerly an optician on staff of the bureau.

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for France, which distributes standardization work among several ministries and only recently has moved to coordinate the various efforts more closely.

The BIPM staff has 12 physicists, eight of them "pure" and four experienced in the work of the bureau. Working with them are 12 very skillful senior technicians.

**Length.** "What measurements do you consider particularly your own?" I asked Terrien. "We make a specialty of length," he replied and described the work that went into the redefinition of the meter. When the change from a standard bar to an optical wavelength was proposed, the US suggested a  $\text{Hg}^{198}$  line, the Germans proposed  $\text{Kr}^{84}$  or  $\text{Kr}^{86}$  and the Russians preferred a standard based on  $\text{Cd}^{114}$ . Starting in 1955 Terrien, who was not then director but an optician on the staff, spent three years studying line shapes. He finally concluded that the  $\text{Kr}^{86}$  transition  $2p_{10} \rightarrow 5d_5$  (now the base of the definition) was best. It made a narrow spectral line, and Terrien could explain its shape completely in terms of Doppler shift, pressure broadening and lifetimes of states.

Unfortunately the line is not entirely symmetrical. To improve upon it as a length standard two courses are possible: One is to recognize the line shape in a Michelson-interferometer pattern and with it specify just which

part of the line is the standard wavelength. The other is to go to a laser method. Lasers, to be sure, have the difficulty that tuning can pull the oscillation away from the natural wavelength. To remedy it you can adjust the laser to a natural absorption frequency. Work is commencing on the scheme. For example the helium-neon laser has several coincidences with iodine and methane absorptions. Probably ten or 15 usable coincidences are known now and 100 might appear with two or three years of work.

In the laboratory, I visited the comparator BIPM uses to compare standard bars with the krypton line. Temperature of the room it stands in is controlled to a few hundredths of a degree, and temperature in its tank to a thousandth. The operator sits next door, directing a light beam along a selected interference path and recognizing scratches on the test bar by signals from optical scanning devices.

**Time and gravity.** Time is closely related to length, or, if you prefer, it has become the same quantity now that measurements of optical frequencies have become possible. The development puts BIPM into a new business. There are no time standards at Sèvres, but there exists the consultative committee on the second. "I am learning now what I must know," says Terrien as he discusses how BIPM may get involved. He feels that with recent improvements of technique the present second based on a cesium transition is the best unit, but the hy-

drogen maser might produce a better one. Laser standards are better in principle, but accuracy with them is not yet good enough to compete.

I stood at the spot where acceleration of gravity is known to eight significant figures. Changing elevation by 2 cm changes the last figure, pointed out Terrien. So would a significant amount of concrete construction in the basement. Then we walked next door where standard cells in temperature-controlled oil baths and standard resistors offer the basis for electrical measurements. Gravity and electrical measurements are closely related. As you know better the weight of a kilogram, you can measure more accurately the forces between coils; forces are related to the standard ampere, and so on.

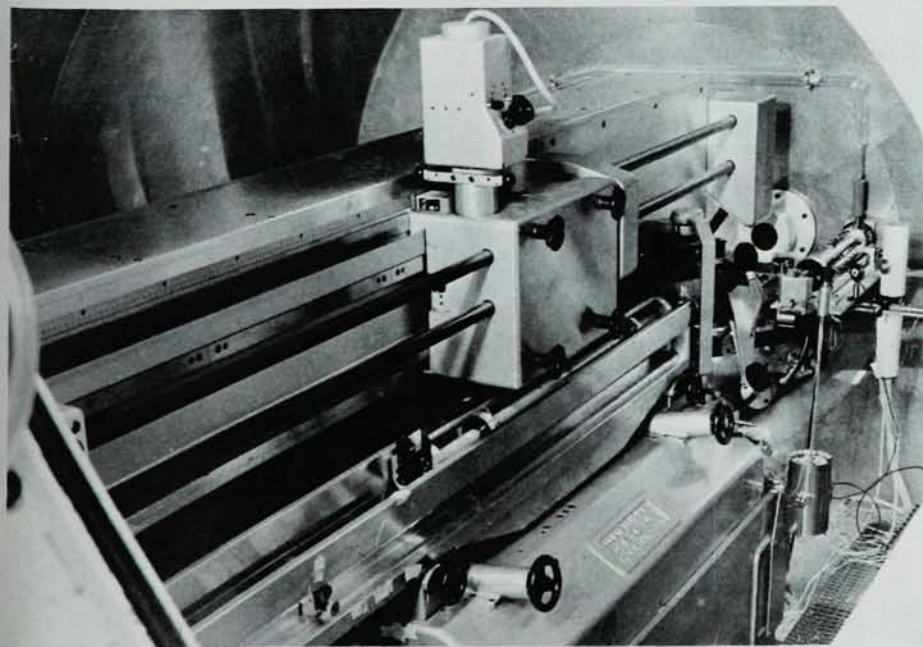
A working group of the committee on electrical units studies measurements of the proton gyromagnetic ratio. Well enough measured, it might some day be a basis for better electrical units.

Another new device that might serve the same purpose uses the Josephson effect: A constant potential appears across a narrow junction between superconducting metals when they are driven with a fixed frequency.

**Radiations.** The newest section of BIPM is devoted to ionizing radiations. I saw x-ray and neutron generators,  $\text{Co}^{60}$  irradiators, free-air and cavity ionization chambers, gamma spectrometers and counting devices for neutron and radioactivity sources. Among unique accomplishments of the section is an absolute alpha-particle spectrograph for maximal possible accuracy. It uses a homogeneous magnetic field that bends alphas emerging from a slit through semicircles and causes them to focus on a photographic plate. Results obtained so far add at least one decimal place to best former measurements. Hopes are for detection of line shapes produced by interaction between alphas and the electron clouds of the atoms from which they come.

Terrien is a careful man whose manner suggests the precision with which French engineers design their cars and vacuum tubes. He says his job makes him travel too much in his efforts to learn what he must know. Like physicists of other times and places he and BIPM appear to enjoy the challenge of making discoveries by resolving the next decimal.

—RHE □



**LENGTH COMPARATOR** operates by remote control in constant-temperature environment. With interferometry it compares standard bars with krypton-86 wavelength.