CHOICE BETWEEN ATOMIC AND ASTRONOMICAL STANDARDS OF TIME

ESSEN AND PARRY[1] described a year ago a frequency standard based on a natural resonant frequency of the cæsium atom, which has been used for calibrating the quartz clock standards with an accuracy of 1 in 10^9 (0·0001 sec. per day). The atomic beam magnetic resonance technique first developed by Rabi and collaborators and used by these authors holds out a prospect of even higher accuracies.

Commenting on this, Sir Edward Bullard[2] has solicited views on the desirability of abandoning the astronomical second for the most refined measurements in view of the high precision of atomic frequency standards now available. His argument runs as follows:

Ephemeris Time, on which the definition of the second adopted by the International Astronomical Union and the International Committee of Weights and Measures depends, is derived from the motion of the Moon If the position of the Moon at any time can be determined to 0·05 sec., a period of four years would be necessary to obtain an accuracy of 1 in 10^9 in time and frequency derived from astronomical observation. Essen and Parry mention Markowitz's proposals for reducing this period to one year; these depend on a reduction of the errors by repetition of observations. Such a reduction would involve a study of systematic errors in star places and in the corrections for differential refraction that would certainly take many years. During this time atomic clocks will be improved, probably by a greater factor than the astronomical determinations.

It thus seems probable that for the foreseeable future the accuracy of the measurement of frequency and of time intervals relative to laboratory standards will exceed that by astronomical means, and that the astronomically defined second is therefore incapable of realization with the accuracy necessary for microwave spectroscopy. The natural way of escape from this difficulty is to define a 'physical second' in terms of the natural period of the cæsium atom, choosing the numerical value so that it agrees as well as may be with the current estimate of the second of Ephemeris Time.

In regard to the above, Clemence[3] directs attention to two consequences that should be well understood before the astronomical second is abandoned by physicists.

The first is, that by using the atom at once as a standard of length and of frequency the units of length and of time lose their independence; wave-lengths and frequencies have a fixed relation to each other, the product of the two being the velocity of light. Hence it is of the utmost importance that the new units should not be exclusively employed; atomic wave-lengths must be compared with the metre from time to time, and atomic frequencies must be compared with the astronomical second. To fail to do so would be unnecessarily to restrict the science of physics at its very foundations, by assuming what can only be verified by experiment.

The other arises from the fact that an atom, while it undoubtedly gives an excellent natural standard of frequency, is not a natural clock. It is probable that two cæsium standards built to the same specifications on opposite sides of the Atlantic would run at the same frequency; but if each were made to control the hands of a clock through a suitable mechanism, the two clocks would *not* indicate the same time (epoch). Even if they could be brought to the same time with enough precision to satisfy astronomers and geodesists—which is doubtful—if both should stop it would be impossible on starting them again to determine how much time had been lost. For actual time-keeping it will be necessary, as in the past, to rely on better mechanisms than man-made ones. The consequence, then, of adopting the new 'physical second' would be to use one second for measurements of frequency and another for actual time-keeping.

Regarding the reduction of the errors of astronomical observations by repetition, he observes that the systematic errors in star places and the differential refraction are not important limitations when periods of a year or more are considered. He estimates that with four dual-rate cameras observing the Moon, an accuracy of 1 in 10^9 in time and frequency derived from astronomical observations can be attained in a year, and probably 1 in 10^{10} in five years. But it would appear that Bullard's argument is not affected by these estimates. He suggests therefore that before specifying the new unit of time, physicists might wait for the end of the International Geophysical Year, by which time a good number of observations of the Moon will have been made, and to compare atomic standards with astronomical ones assiduously in the meantime.

This question has also been discussed at length by Abraham[4] more recently. He observes that the essential requirements for the fundamental unit of time are that it must be the same whenever and wherever it is needed and that it must be susceptible of exact measurement. (The actually observed quantity need not be constant provided its relationship to the fundamental unit is known.) There can, moreover, be only one fundamental standard, and this should be the standard of Ephemeris Time. This standard should be retained because its stability and permanence are independent of its users, and also because it can be measured with sufficient accuracy for the purpose. In his opinion atomic clocks are to be recommended only as the precise and accessible sub-standards.

1. Essen and Parry, J. V. L., *Nature*, 1955, **176**, 280.
2. Bullard, E. C., *Ibid.*, 1955, **176**, 282.
3. Clemence, G. M., *Ibid.*, 1955, **176**, 1230.
4. Abraham, H. J. M., *Austr. J. Sci.*, 1956, **18**, 103.

THE INTERNATIONAL ATOMIC ENERGY AGENCY

AN international agency for the development of the peaceful uses of atomic energy is to be established early in 1957, subject to the ratification of the statute by a special assembly of the UN to be held in September.

The agency will encourage and assist research, development and the practical application of atomic energy for peaceful uses throughout the world and will foster the exchange of scientific and technical information as well as the exchange of scientists and of experts among nations. Its chief purpose would be to act as a "bank" to receive, store and issue uranium fuels and other atomic materials and thus to make them available to the industries of the world beyond the borders of the few countries that can produce these materials.

Under the present draft of the statute, the agency could accept the 440 lb of uranium-235 which the United States proposed in 1954 to contribute for international purposes, the 44 lb. allocated by the United Kingdom, and the unspecified amount that the Soviet Union has offered. None of these offers have, of course, been made to the agency as such, since it is not yet in existence. But the total would represent a large capital endowment. The U.S. Atomic Energy Commission has set a price of $ 25 a gram on uranium-235, so that the amount proferred, 200,000 grams, would be worth five million dollars.

Even broader is another function of the agency. It will make provision for materials, services, equipment and facilities to meet the needs of research and the practical application of atomic energy for peaceful uses, including the production of electric power, with due consideration for the needs of the underdeveloped areas of the world This seems to envisage a large function of leadership in atomic development. The agency is also authorized to acquire or establish any facilities, plant and equipment useful in carrying out its authorized functions, whenever the available facilities in the area concerned are inadequate or unavailable on satisfactory terms.

Since the fissionable materials could be diverted to military purposes and since their use in atomic reactors involves the production of materials that emit radiations, the Agency will also establish and operate a complete system of safeguards, both to prevent misuse of materials, equipment or information and to assure the protection of health, life and property from possible hazards This includes the establishment of a staff of inspectors who will be responsible for the maintenance of safeguards and protective measures, not only by the Agency itself but by member States engaged on projects under agreement with the Agency.

There is no specific provision in the draft of the statute for any study or action by the Agency with regard to the training of atomic specialists or the introduction of educational improvements that the atomic age will demand in many countries. Neither is there any consideration of the vast economic and social consequences in industry, agriculture, medicine and society. Many of these fall within the scope of present organs of the United Nations and may therefore be left to the latter or undertaken co-operatively.—UNESCO.