and in particular whether the balance of activity and initiative in nuclear development between the Central Electricity Generating Board and the Atomic Energy Authority is correct. Here again questions of Government structure may also arise, particularly in respect of the position of the Ministry of Technology.

Other questions suggested for consideration in the Broadsheet are the structural division of electricity supply for England and Wales and for Scotland, and whether there is scope for forms of combined technical development between the industries, and possibly coal or oil also, that are being ignored at present because of the structural separation and competition. The Broadsheet also questions whether limits should be put to commercially competitive promotion between the nationalized fuel industries, and how far they should be obliged to keep their investment policies with the Government's forecasts of solid and other smokeless fuel requirements arising from application of the Clean Air Policy. The principles to be followed in permitting these nationalized industries to diversify their activities in the fields outside those in which they now operate also require definition. The Broadsheet hints plainly that the consumer is not at present adequately informed of the price trends in the various fuels. The present structure of the Ministry of Power also requires consideration in the context of how far it conduces to a sensible co-ordination of national energy policy and to objective assessments of conflicts of policy between the nationalized fuel industries.

It should also be remembered that some of the technological changes that could occur in the supply of energy would bring with them new questions about the structure of the British fuel industries. For example, if large-scale natural gas-fields were in fact found in the North Sea, the present gas industry, with its virtual monopoly and its commitment to manufacture gas at lower calorific values, might not be the ideal instrument to introduce the natural gas into the British market. Possibly a measure of competition should be introduced when gas supply becomes more and more based on the end-products of oil refining. Nor should it be without due consideration whether the economies of scale in supply or in transmission are as compelling, or whether monopoly is as appropriate a form of organization for gas as for electricity supply. The Broadsheet offers no answers to these problems, but it does suggest that urgent public consideration should be given to them and particularly to the determination of the right order of priorities. This is especially so in regard to what protection the fuel industry should receive, particularly British coal, and in what form.

U.S. STANDARD FREQUENCY AND TIME SERVICES

A REVISED (1965) publication of the United States National Bureau of Standards * gives a detailed and illustrated description of the services provided by the Standard Frequency Stations now operating in Washington, Hawaii and Colorado. The first is the well-known station, *WWV*, at Greenbelt, Maryland, which has been in operation since 1933, and now provides services of radio and audio frequencies, musical pitch, time signals and the departure of these from astronomical time; propagation forecasts and geophysical alerts are also issued from *WWV*. An additional service was started from Hawaii in 1948; but this is confined to radio frequencies, time signals and their corrections. In 1963, two low-frequency transmissions were added from stations at Fort Collins, Colorado. One, *WWVB*, broadcasts continuously on the standard frequency of 60 kc/s, and provides time signals and corrections, while the other, *WWVL*, broadcasts continuously on the standard frequency of 20 kc/s. The frequencies of all these services are held stable in general to a few parts in 10^{11}, and they are ultimately referred to the resonance frequency of caesium, which is measured in terms of ephemeris time.

All the carrier and modulation frequencies at *WWV* and *WWVH* are derived from precision quartz oscillators of high stability. These are offset from the standard by a small but precisely known amount to reduce departure between the time signals as broadcast and astronomical time, U.T.2. Although the latter is subject to unpredictable changes readily noted at this level of precision, it is expected that the present offset—150 parts in 10^{10}—established in 1964, will remain in effect for the present calendar year (1965). For the benefit of users who wish to make direct comparisons of absolute frequencies, *WWVB* has been transmitting on 60 kc/s with no offset since January 1, 1965.

A comprehensive description, with diagrams, of all these services is given in the report, together with details of the propagation forecasts and geophysical alerts which are disseminated at hourly intervals. The forecast announcement tells users, in a simple code form, the condition of the ionosphere at the regular time of issue, and the quality of radio services due to propagation conditions to be expected during the next 6 h. A series of letter symbols is used to indicate the current geophysical conditions and give notice of any outstanding solar or geophysical events which are expected or which have occurred in the preceding 24 h.

The revised issue of this publication will be welcomed by all users of frequencies and time signals, as well as by research workers in the fields of radio and the geophysical and solar sciences. R. L. SMITH-ROSE

* United States Department of Commerce: National Bureau of Standards. Miscellaneous Publication 236: *Standard Frequencies and Time Services of the National Bureau of Standards*. Pp. 8. (Washington, D.C.: Government Printing Office, 1965.) 15 cents.

COMMERCIAL NUCLEAR POWER STATIONS IN BRITAIN

THE principal contents of the July number of the *Journal of the British Nuclear Energy Society* (**4**, No. 3; 1965) consists of the texts of the six papers contributed by members of the Central Electricity Generating Board and the South of Scotland Electricity Board and presented to the symposium on the performance of commercial nuclear power stations in the United Kingdom, which was held at the University of Leicester on June 30.

H. M. Carruthers, in his discussion of the evolution of magnox station design, points out that, in the nine years since the first Calder Hall reactor went critical, some thirty-five reactors of this basic type have been built, of which twenty-six are in Great Britain. The reactors during this period have developed from a small unit of about 40 MW(e) output to one of nearly 600 MW(e) with at the same time reduced capital and generating costs. The main technical improvements in layout, shielding, refuelling methods, pressure circuit technology and fuel element design since the start of the commercial magnox programme are described in some detail.

The commissioning of a nuclear power station requires not only the setting of the plant to work safely and

reliably, but also at the minimum cost computed over the total life of the station. The history of the commissioning of the Berkeley and Bradwell stations is reviewed by C. D. Heath and D. J. Silverlead, and in their assessment they direct attention to the need for greater flexibility in the timing of the various tests and measurements, improvements in the planning of construction and plant installation, and some simpler form of commissioning organization.

Two papers deal with the performance of reactor cores and materials and of power station plant, and a third with power station maintenance. Of the nine civil nuclear stations, Berkeley and Bradwell have had more than two years' full-power operation and Hunterson one year. Serious defects have been experienced at all three stations and the extra fuel costs have amounted to about six and a half million pounds. The major defects were in the fuelling routes, turbines and boilers. Experience suggests that more reliable operation in the future will occur. With regard to maintenance, it is emphasized that health physics requirements are an important factor in maintenance planning and that future stations should be better planned and equipped for the maintenance of radioactive equipment.

The final paper in the symposium, by P. H. G. Holbrook and A. C. Horne, deals with some of the special problems, not necessarily technical, which arise in the operation of a nuclear power station. The provisions of the Nuclear Installations Licensing and Insurance Act, 1959, the Radioactive Substances Act, 1960, and the Generating Board's safety regulations have to be enforced and accordingly appropriate inspectorates and organizations have to be established. The increased automation of future stations, with centralized control and computational operation, may lead to a change in the pattern of station organization with economies in technical man-power and less risk to personnel.

S. Weintroub

PHYSICS EDUCATION

IDEALISM and iconoclasm were offered in equal proportions by speakers at the International Conference on the Education of Professional Physicists, held in London during July 15–21. The meeting was arranged by the Institute of Physics and the Physical Society for the International Union of Pure and Applied Physics, and attracted participants from twenty-five countries.

Lord Beeching (Imperial Chemical Industries, Ltd.), in a forthright introductory speech, deplored the attitude of university departments which, while disclaiming interest in vocational training, were in fact preparing students exclusively for the vocation of fundamental research. It was, he asserted, not in the public interest that academic research should be presented as the best career for physicists at a time when the industrial, economic and political problems of the community were increasingly dependent on the widespread use of science and technology. Though the Government had great responsibilities in the deployment of scientific and technical resources, only a handful of Junior Ministers had any scientific training. The cause of this deficiency was in the attitude which asked: "Why should we train a good physicist, only to have him wasted as a politician?"

Students of physics must learn that they were not going to be employed exclusively in the narrow practice of their specialty, Lord Beeching continued. Many graduates would find careers in which knowledge of physics was only a small part of the requirement. His own company employed 290 physicists, of whom half held posts not necessarily filled by physicists and about 10 per cent were doing work for which scientific qualifications were not essential. The object of the Government and the universities should be to create an apparent surplus of scientists, many of whom would move into management, administration and politics.

Most of the subsequent contributors were concerned with the scope and content of the undergraduate curriculum, but there was lively discussion also on the extent to which industry's needs were fulfilled by the products of the universities.

A discussion of the young physicist's training and progress in industry, offered by G. S. Bosworth (English Electric Co., Ltd.), was strongly criticized by A. B. Pippard (Cavendish Laboratory, Cambridge) as showing how second- or third-class people could be turned into useful members of an industrial team, while offering nothing to attract the first-class scientists who were badly needed in British industry but were repelled by the Philistine attitude of prospective employers.

Extreme differences of opinion such as this were infrequent. It was generally recognized that the primary purpose of a university was the advancement of learning and that an industrial concern would fail unless it was conducted to make a profit. Efforts to secure closer collaboration between the university and the industrial community in undergraduate and postgraduate work were reported from several parts of the world; it was agreed that physicists were somewhat better prepared for a practical career in countries such as Holland, where industrial scientists and engineers had a substantial role in academic research and teaching.

Discussion of the content of the curriculum embraced three main topics: (*a*) mathematics, (*b*) laboratory work, and (*c*) lectures. Commenting on the importance of adequate mathematical training, M. Y. Bernard (Conservatoire National des Arts et Métiers, Paris) proposed, not entirely in jest, that special courses should be provided for university teachers of physics, who might otherwise be embarrassed by the superior mathematical ability of their students. The consensus of opinion in France, he reported, called for three kinds of instruction. Professional mathematicians should be responsible for about 25 per cent of the undergraduate's course, dealing with topics where a rigidly logical approach was valid. A physicist should have about 40 per cent of the available time, to cover inductive methods and the development of general laws. The rest of the course should be devoted to exercise classes.

More radical views were asserted by Bernard Friedman (University of California), who condemned the "pernicious influence of sound old-fashioned courses in classical mathematical physics". Up to the end of the nineteenth century, he said, important problems giving insight into the physical world were tackled and solved by the use of special functions, separation of variables and often complicated techniques of integration. These methods were now out of date, partly because of the increasing mathematical sophistication of modern physics and partly because of the rapid advance in electronic computing. When numerical results were required, the computer would generally give more accurate results with less effort. If, on the other hand, a qualitative approach was attempted, mathematical techniques of a more abstract kind were now available.

To understand the mathematical content of present-day physics, the student must be trained in linear algebra, probability and Markoff processes, functional analysis, group representations and Lie algebras. Time does not allow the prospective physicist to follow the standard mathematical courses on these topics, but a briefer curriculum must not be allowed to degenerate into a collection of recipes for solving standard types of problem. Emphasis