

vessel. The tritium doubling time would perhaps be of the order of one year. The reactor would also be a very fruitful source of neutrons, but would produce far less radioactive waste than fission reactors. More recent calculations, Professor Rose says, have shown that fusion reactors would produce one ten thousandth as much overall radioactivity as fission reactors of comparable size. Another advantage is that when fusion reactors are shut down, the total afterheat would be tiny—something like 60 kilowatts for a reactor of 10,000 to 15,000 MW. A large fission reactor, by contrast, may be nominally shut down by insertion of the control rods, but nevertheless goes on producing very large quantities of heat—perhaps 10,000 times as much as the fusion reactor the same size.

One of the important results of Professor Rose's report (apart from sustaining optimism among plasma physicists, which is itself important) may be to redirect some of the research effort. Professor Rose is particularly keen that more work should be done on the effects of the energetic neutrons on the reactor vessel. There is no experience of radiation damage at these extreme energies. There is also the question of injecting fuel into the reactor, which may turn out to be a great deal harder than it sounds. But Professor Rose concludes that a fusion power station, if feasible, would be cheap. Capital costs in the region of £12 per kilowatt and a generating cost of 0.3 pence per kilowatt look good. By the year 2000, of course, there is always the chance that they will have been overtaken by something even better.

## Steady State Supported

THE steady state theory of cosmology still has a great deal of life in it, according to Professor Fred Hoyle, director of the Institute of Theoretical Astronomy at the University of Cambridge. Professor Hoyle, giving this year's Bakerian Lecture at the Royal Society last week, discussed how the evidence put forward against the steady state theory can be overcome. He emphasized, however, that his lecture—a review of recent developments in cosmology—was an entirely personal view of the subject. His interpretation of counts of radio sources, for example, certainly differs from that of several other astronomers.

The most recent challenge to the steady state theory, Professor Hoyle said, was the discovery about three years ago of the microwave background radiation. This is radiation at microwave frequencies which seems to permeate space and corresponds to a black-body temperature of about 3° K. One school of thought believes the microwave radiation is a by-product of events early in the history of a so-called big-bang universe. One of the reasons for this interpretation is the difficulty in understanding the radiation in terms of emission from existing radio sources which are not expected to emit strongly enough at short wavelengths to account for the measured intensities. The microwave background has consequently been widely held to be a fossil relic of a big-bang cosmology. Professor Hoyle said, however, that there is evidence coming to light that the spectra of an appreciable fraction of radio sources have an upturn toward higher frequencies. This means the microwave background may yet be explained by emission from radio sources, and that the steady state theory will be upheld in this respect.

In his lecture, Professor Hoyle went through the crises the steady state theory had so far faced. In particular, he discussed the way in which counts of radio sources can distinguish between different cosmologies. The practice is to count the number of radio sources  $N$  brighter than a certain flux  $S$ , and to plot  $\log N$  against  $\log S$ . Various cosmologies predict different values for the slope of the straight line through the points, the steady state theory predicting a slope of  $-1.5$ , for instance. Professor Hoyle said that counts of radio sources in the Cambridge 4C and 5C surveys agree with the steady state cosmology, but that the earlier 3C survey gives a steeper slope more in keeping with the big-bang theory. To understand the steep slope given by the 3C survey in terms of the steady state cosmology, the radio sources making up the survey can be classified according to their appearance and the slope of the  $\log N$ - $\log S$  curve evaluated for each class. Objects which look like radio galaxies lead to a slope of  $-1.4$ , and sources identified as quasars have a slope of  $-1.56$ . The remainder of sources in the 3C survey, which could not definitely be identified as quasars or as radio galaxies, contributed a slope of  $-2.5$ . Professor Hoyle says the disagreement of the 3C survey with the steady state theory can thus be attributed to the contribution to the counts of sources the nature of which is unknown, and which therefore may have no cosmological significance. New counts of radio sources now under way in the southern hemisphere may help to resolve this question.

Another criterion for distinguishing cosmologies involves the red-shift of distant objects. The technique is to compare the observed relation between red-shift and visual magnitude with the relation expected for various cosmologies. All cosmologies predict the same relation between red-shift and visual magnitude for comparatively local objects, however, and it was not until the discovery of the quasars, with their large red-shifts, that red-shifts could be used by cosmologists in this way. Although measurements of quasars tend to support the big-bang theory, there is doubt whether their large red-shifts are in fact of cosmological significance at all. The problem seems to hinge around indications that quasars are large masses confined in volumes comparatively small by astronomical standards. This suggests that their large red-shifts may be a gravitational effect, yet the spectra of quasars are not what are expected for emission in a high gravitational field. Further, some quasars seem to show more than one red-shift, and up to nine red-shifts have been associated with one object. This may mean the emission is coming from differing positions in a strong gravitational field, or an alternative explanation is that the quasar is ejecting clouds of gas at speeds approaching the speed of light. The uncertainty about what quasars really are makes their cosmological significance much less convincing.

## Daresbury's Plan

THE Nuclear Physics Laboratory at Daresbury sees as one of its functions the design of accelerators which may form the future development of the site. At the moment, for example, the Daresbury laboratory is completing a design study for an electron synchrotron producing energies which may go up to 20 GeV. One of the features of the Daresbury design is that it uses

the NINA accelerator to inject particles at 3 GeV into the machine. The small size of the beam at this energy seems to give some saving in the size of the magnets involved.

The only electron accelerator with an energy reaching 20 GeV is the linear accelerator at Stanford. Such machines produce beams of particles in pulses to allow for cooling of the radio frequency generators and waveguides. The accelerator envisaged by the Daresbury group has the advantage of a longer duty cycle than the Stanford accelerator, however, which would make it a more versatile machine. What chance the Daresbury design has of being built is a different matter. At an estimated cost of just over £3 million it may be good value for a 20 GeV machine, but the likelihood of the Science Research Council finding this kind of money must be small.

## Students and Vice-Chancellors

ON the surface, at least, the confrontation between British university students and their vice-chancellors is exceedingly decorous. Last week-end most of the executive heads of British universities gathered in Downing College, Cambridge, where they apparently spent a good deal of their time alarming each other with previously unpublicized stories of insurrection or the threat of it. It is not therefore surprising that the vice-chancellors should have issued a statement after their meeting which roundly condemned the wild goings-on of recent weeks. "We utterly condemn, and will resist, attempts by extremist groups to obstruct or disrupt the life of the universities. Such activities destroy freedom of speech and the freedom to learn, and we believe that they are entirely unacceptable to the overwhelming majority of members of the British universities, staff and students alike." The same statement went on to acknowledge the constructive interest of a large part of the student body in the affairs of the universities, promised that there "is scope for them to do more" but insisted that there are "important academic and financial matters" on which the members of universities with "continuing responsibility" must continue to be in charge. The statement finished with a promise to work out "suitable arrangements" within individual universities and, in particular, to consider the "specific and important points" to which the National Union of Students has drawn attention.

By itself, there is no means of knowing whether this statement will satisfy the somewhat belligerent demands which the National Union of Students made public just over a week ago, although it is also possible that some of the bellicosity which the students have been showing stems from the wish of the students' organizations not to become entirely alienated from their more radical supporters. Briefly, the students are asking for "effective student presence on all relevant college committees", staff-student control of discipline, student control of their own organizations and staff-student discussion of course content and teaching methods. On examinations, the students are looking for prompt "radical reform", though it is not entirely clear what they mean by this. One tendency is to ask for the abolition of formal examinations, but another asks that there should be some kind of external assessment of the grades which students are awarded. In one sense, however, the National Union of Students

appears to have forced its own hand by asking that the programme of reform should be completed before the beginning of the next academic year. Unless somebody does something to make this hope come true, there is at least a chance that, when the new academic year begins, the first signs of trouble will show themselves within the students' organizations.

## Gas-cooled Fast Reactor

DESIGNS for fast breeder reactors seem to be proliferating almost as fast as those for conventional thermal systems. Several months ago the European Nuclear Energy Agency announced that it was investigating the possibility of building a fast reactor cooled either by gas or by steam, in contrast with the liquid sodium cooling which is being used by the UK Atomic Energy Authority, among others. Now Gulf General Atomic in the United States has announced a \$5.3 million joint project which is intended to speed up the development of a gas-cooled system. The project, to be jointly supported by Gulf and twenty-one United States electric power companies, complements another study already in progress and supported jointly by Gulf and the Swiss Federal Institute for Reactor Research at Wurenlingen.

The project just announced by Gulf covers fast reactor core design and development, systems and component development, and safety analysis. Gulf hopes that the system will have a high breeding gain—1.5–1.6—giving low fuel costs, and that the capital cost of the system will be less than that for liquid metal-cooled systems. If all goes well, Gulf vice-president Dr Frederick de Hoffman visualizes the building of a full-scale power station by the early eighties.

## Good Food Guide

ANYBODY worried about the colour of processed peas, the use of silicones by plastic surgeons or the danger of going blind from eating fresh cassava, should seek advice from the British Industrial Biological Research Association. BIBRA is supported jointly by industry, Government and a few charities and assesses the possible hazards to health of materials which member companies develop, manufacture or use. These materials are chiefly used in food technology—food additives and packaging—but also include drugs, cosmetics, toiletries and pesticides; the association hopes eventually to cover all potential environmental hazards.

The association lost its first director, Dr L. Goldberg, to the United States a year ago; he has been replaced by Dr R. F. Crampton, a biochemist who was the medical director of Abbott Laboratories, Ltd. At the opening of a new £60,000 extension, Dr Crampton stressed that the association is unique in Great Britain and Europe, and possibly the world, in the way it is organized and financed. For every £100 donated by British industry, the Government contributes £150. In addition, the Nuffield Foundation is contributing £30,000 a year for six years and the Wellcome Foundation will be sponsoring a study on the neurological effects of cyanide and fresh vitamin B<sub>12</sub>—found in fresh cassavas and suspected to be the cause of blindness and paralysis in parts of Nigeria.

In return for these funds, which totalled more than £250,000 last year, the association acts as a consultancy