hypothesis led to the phenomena of frozen modes at low temperatures.

Biographical Notes

We end this brief summary with a few biographical and historical notes. Maxwell was born in Edinburgh in 1831 into a comfortable middle class family, which almost immediately moved into a country house in the estate which his father had inherited. He went to the Edinburgh Academy School from 1841-47 and then to Edinburgh University from 1847-50 ; it was here that his interest in colour vision was first aroused. Proceeding to Cambridge in 1850 his unusual talents began to be recognized ; he was second wrangler and first Smith's prizeman in 1854 and was elected to a Fellowship at Trinity College in 1855. In 1856 he left to take up an appointment as Professor of Natural Philosophy in Marischal College, Aberdeen. His most important publication during the Cambridge period was a paper of 75 pages "On Faraday's Lines of Force". He spent four years at Aberdeen during which he won the Adams Prize for his work on Saturn's rings. In 1858 he married Katherine Mary Dewar, daughter of the Principal of the College ; there were no children.

In 1860 he moved to King's College, London. The five years which he spent there were the most fruitful of his life, and saw the publication in 1861-2 and 1864 of his pioneering classic papers on the electromagnetic field. In addition he supervised the experimental determination of electrical units for a British Association Committee. In 1865 he resigned his Chair at King's and retired to the family home in Glenlair, Scotland. Much of his time and energy was now devoted to the planning and writing of his treatise on Electricity and Magnetism.

Maxwell emerged from retirement in 1871 to take up the newly established Chair in Experimental Physics at Cambridge. During the final years of his life he initiated the great Cavendish Laboratory tradition which was implemented by his successors Rayleigh, J.J. Thomson, Rutherford, Bragg, Mott and Pippard. His students, few in number, but of the highest quality, included Niven, Ambrose Fleming, Glazebrook, Poynting, and Schuster.

If one turns to any page at random in Maxwell's collected works one is likely to find a feature of novelty and interest. In the words of the late Charles Coulson, "there is scarcely a single topic that he touched upon which he did not change almost beyond recognition".

JET — Not Just a Technical Challenge

Western Europe's Joint European Torus experiment for studying the tokamak configuration under near reactor conditions is a pioneering operation not only in science but also in organizational terms. A new approach to international development is required that can envisage application as well as research.

Cranes, bulldozers and excavations in the field alongside, and a group of black and white temporary buildings next the football pitch, mark the presence of the Joint European Torus project at the U.K. Atomic Energy Authority's site at Culham. The hopes and plans of so many years are now being translated into concrete terms and Europe's largest tokamak will soon begin to take shape.

Despite its uniqueness as the first Joint Undertaking to be set up under the European Communities, JET suffers in more than one way from being tied to atomic energy structures that have aged under the effects of many years of frustrating work.

In the fifties, the new technology of nuclear power brought together the most innovative and energetic scientists and engineers of their day; thirty years and many disappointments later, it is not easy to recapture that pioneering drive, particularly when recruitment in so many organizations has stood still and the younger men have gone elsewhere. A major problem for JET is building a team that has all the fire and inventiveness of the old days — or rather of the new days — particularly in regard to engineering; physicists of quality are more easy to come by but their rôle at the moment is less crucial than that of the engineers. JET, at this juncture, is primarily an engineering experiment, where the goal is to build a device that will confine and heat plasma to near reactor temperatures. In the experimental programme which follows completion of construction, the physicist will come back into his own. Nevertheless, it must be recalled that JET has the explicit purpose of furthering the techniques for achieving economic power generation. There is no spare effort within the joint programme for plasma physics research for its own sake; that has to be funded from other sources.

It is of course logical that thermonuclear fusion should be seen as a section of nuclear power development, partly because historically it developed as an adjunct to fission, partly because many of the technical problems such as fast neutron fluxes and a radioactive environment are similar to the problems met in fission. The bond may even become stronger in the future, as some authorities are suggesting that the main use of D-T fusion reactors, at least in the initial stages, will be to produce fissile material for a fusion-fission cycle. The days are gone when fusion is publicized as offering in the near term, clean, illimitless power from the sea. Instead, there is a more sober awareness of the difficulties of getting even the D-T reaction to work and then transforming the energy efficiently into a transportable form.

On the technical side, fusion has inherited the rigorous scientific tradition and the high quality engineeing standards of fission to its advantage, but at the same time it suffers from being enmeshed in organizations that were created before the magnitude and complexity of the research, development, industrialization problem were understood and when these three processes tended to continue as separate and independent activities. International cooperation at the research stage was not unknown in fission but it rarely carried over into the development phase.

Collaboration in fusion has been going on quietly over the past two decades. JET, however is something new, going beyond the liaison between individual departments that has characterized fusion research in western Europe to date. As such it will require a new orientation of priorities that can adapt to a progressive advance on a common front through to industrialization — a process which, every bit as much as research, should be seen as requiring an international approach.

Funding

Viewed against the public agonising over energy sources, funding of JET, totalling 184.6 M EUA at January 1977 prices for the 5-year so-called construction phase, has not been particularly generous, and provision for indexing the budget to allow for price escalations was not made automatic. As such, the international supervisory bodies can easily find themselves in the invidious position of trying to

The value of the EUA varies but is currently the equivalent of about 2.3 Sw.Fr.

support the Project while defending budgets at home against the inroads of international inflation. It will be recalled that JET is financed 80 % by the European Communities, 10 % by the associated institutions (national laboratories, engaged on fusion research within the context of the Communities' coordinated fusion programme) and 10 % by the U.K. as host country. The mix may not be ideal. However, these are early days — the agreement setting up the project was signed in May 1978 — and there is no lack of determination on the part of the Directorate to see that JET is not only a major step forward in controlled fusion technology but is equally a step in the right direction in international collaboration.

To hear at first hand how the work is progressing, *Europhysics News* in September talked to the **Project Director,**

H.-O. Wüster.

" We have now 175 people actually working on the project (out of the 320 envisaged) on site. Civil engineering has been started, and about three quarters of the contracts in terms of value have been let to industry for the device itself. These are for the most part in the transition stage of moving from prototype to series production. Effectively all the big contracts for the device have been placed and what remain are about half the power supply systems and certain auxiliary systems such as cooling. Otherwise the most interesting part technically (if not so large financially) still to be finalized is the additional plasma heating. Altogether progress so far is following well enough the Project schedule".

How good has the design study proved to be, now it is a question of building?

" In all the main aspects we have not had to go back over what has been done. What has been necessary is to stop people " improving " on their designs but this has not been too difficult as, in spite of the total uncertainty hanging over the members of the study team who for two years worked on quarterly contracts, much of the design was brought to the stage of being ready to go out to tender. The parts that were allowed to trail because there was just not the effort available were the auxiliary systems for the most part. For these we are able to contract out part of the design work to industry which in effect increases temporarily our own design effort.

We plan to have the control room and the assembly part of the main hall available next Summer so that control systems can start to go in, and we can begin to assemble the device when the pieces arrive in the second half of next year. Some of the coils will even be delivered this year. Components are scheduled for assembly and testing by the end of 1982. From then on the experimental programme begins, because the device itself is the experiment. "

And costs ?

" Taking into account the real inflation since January 1977 we are still inside the original estimates, and we hope to remain that way. Due to the system adopted in the Communities of budgeting on the basis of 5-year plans of which the present runs from 1976-1980 we shall be presenting an up-dated budget for the period in the next plan that covers the remainder of the construction phase, notably 1981-83 and takes care of inflation over the current period. Theoretically this could present problems but as far as we know the attitude of all governments involved is positive ".

When JET enters the experimental phase will any basic restructuring become necessary?

" From a formal point of view no — but evidently the style of work will change as some builders become operators. The important development to which we look forward is a strong participation in the experimental programme by the laboratories in the different countries. Design work though will not stop, there will be a continuous evolution in the device itself for as long as this is seen to be useful. Come the time when a complete rebuild is necessary then that will require more fundamental changes. But at the moment it is impossible to prejudge whether it will be sensible to build a larger torus; we must wait to see the first results from JET itself and also the developments that take place elsewhere in the world. Financial restraints will almost certainly prevent our going on too rapidly.

It is not of course too early now to consider what might be the stage after JET, recognizing that the next device, if it is to be useful, would cost much more than JET. The problems that JET will not be able to tackle are essentially related to size. Awareness of this has encouraged the International Atomic Energy Agency to launch the INTOR Study Group to coordinate the projects in Europe (including of course the USSR) and those of the USA and Japan both of which are taking fusion very seriously. So far the will to cooperate seems rather strong. "

With more money could one do more now?

" Yes if we could get hold of the right people. What is needed too is the confidence that financial support will be forthcoming regularly so that planning on a long-term basis — say 10 years could be undertaken. Just increasing the injection of money on an ad hoc basis is unlikely to yield a good return, whereas if we could foresee a steady investment and we could then attract the best people into the field, progress could be significantly faster. "

Evidently much of the research must be concentrated round the fusion devices; how can the smaller laboratories and Universities contribute ?

Without question a great deal can be done outside the big laboratories in materials research for example; the question then becomes: is this basic research with a strong individual content or is it really applied research directed towards the realisation of a reactor. If the latter, it needs central coordination and must be governed by the technological needs. In other fields of applied research, it is not unusual to find specific areas with a strong fundamental content where the Universities play an important, even essential rôle. There is no reason why fusion need be very different. What we want to avoid is large organizations finding in fusion a new bandwagon which then careers off on its own, swallowing resources without contributing very much. At the international level, this is not so easy to control.

But if we are attentive we can look after such aspects. What concerns me more is that if we think beyond JET, the shortage of engineers and those with high technological competence is likely to be the limiting feature to progress — more serious even than it is today. We risk not creating that continuity which results in bright young people coming in and growing with the subject, creating a store of experience that becomes invaluable in future years. Turnover is also necessary but we rely too much on industry at the moment to provide the know-how, and important though it is for industry to be involved, a central core of highly specialized people is vital for the future, especially in an international activity. "