The JET project and nuclear fusion

European File

In 30 years' time, the world's population will have grown to 12 billion, according to the most recent estimates. World energy needs will be three times what they are today. European experts say that there are three new energy sources that could be exploited on a large scale to cope with this increased demand: nuclear fission, solar energy and controlled thermonuclear fusion. Research into the peaceful exploitation of nuclear fusion is only just beginning but already the European Community along with the United States, Japan and the USSR, has surged to the van of those countries who plan to harness this new energy source. This is the only field in which all research being carried out in the Community is closely integrated. European governments have joined forces to build one of the most powerful experimental installations in the world, the JET (Joint European Torus), which is similar in its technical conception to future fusion reactors.

What is controlled fusion ?

The most obvious example of thermonuclear fusion is the sun, which is itself a gigantic reactor. The energy it produces comes from a synthesis of a helium nucleus from two lighter nuclei. Scientists based their idea for a nuclear fusion reactor on this principle. The nuclei normally used are deuterium and tritium, two isotopes of hydrogen. Their fusion produces a helium nucleus, a residual particle (a neutron) and energy. This energy is then transmitted — as in the case of nuclear fission — to heat exchangers and converted into electricity or mechanical energy.

Commission of the European Communities
Directorate-General for Information,
Rue de la Loi 200 - B-1049 Brussels

12/82
June-July 1982

In what way does nuclear fusion differ from nuclear fission ? Essentially, in the nature of the nuclei used. The instability of very heavy nuclei is exploited in 'classical' nuclear reactors to obtain energy, by the disintegration of uranium (or plutonium in fast breeder reactors) into lighter nuclei. The phenomenon is sustained by a chain reaction. The procedure is reversed in fusion since a heavier element is obtained from light nuclei, previously reduced to a 'plasma', a sort of gas with special characteristics.

Although the theory sounds simple enough, the practice is far more complicated. There are several technical difficulties still involved in thermonuclear fusion:

☐ In order to trigger a sufficient number of fusion reactions, the deuterium-tritium mixture has to be heated to a temperature close to 100 million degrees, which has so far only been achieved for too short periods and at too low densities.

☐ Once the fuel has reached this temperature, it has to be kept in a condition for combustion and for that it has to be confined in a limited volume for a given period. Two ways of achieving this are currently being studied: inertial confinement, using mainly lasers, and magnetic confinement.

☐ Beyond the initial confinement, the thermal, mechanical, chemical and neutron load stresses that the reactor walls will have to withstand are enormous and require very considerable materials research. The inside of the reactor, continually bombarded by highly-charged neutrons must be constructed from very resistant materials. From this point of view, fusion poses a substantial technological challenge.

In the longer term, however, fusion promises certain advantages:

☐ Firstly, its energy potential. It has been estimated that the amount of energy generated by the fusion of one gramme of the deuterium-tritium mixture is equal to that produced by the internal combustion of over 10 000 litres of petrol.

☐ Secondly, the independence that it would give Europe, whose domestic energy resources are currently very low, with over half its requirements having to be imported. Deuterium can be found in large quantities in sea water. Tritium can be produced from an element which is abundant in the Earth's crust, lithium. When bombarded with neutrons, lithium produces tritium and helium. Since fusion produces neutrons, the core of the fusion reactor simply has to be covered with a 'blanket' of lithium to renew the required quantities of tritium.

☐ Finally, the safety factor. The only radioactive element used is tritium and this is produced inside the reactor and does not therefore have to be transported. The 'ashes' from the fusion reaction are not radioactive, like those produced by fission. Finally, the quantity of fuel in the reactor is sufficiently small to limit the impact of any accident.

Why Community action ?

There are several factors justifying Community action in nuclear fusion:

- ☐ The size of financial and human resources required are beyond any individual European country's capacity, particularly since it will take until the end of the century, if not longer, to reach the final stage, the construction of a reactor.

- ☐ All Community countries have common energy needs.

- ☐ If it succeeds, the European reactor will have a truly continental home market.

The coordination of European controlled thermonuclear fusion research began in 1957, with the creation of Euratom (the European Atomic Energy Agency). The main activities of the new agency were the applications of the atom for energy purposes, the study of controlled thermonuclear reactions and the applications of radioisotopes and radiation.

At that time, research in the Community countries into fusion had hardly begun. Euratom concluded association agreements with national research centres and from then on the Community participated in the definition, financing and coordination of research programmes. National laboratories opened their doors to researchers from the Joint Research Centre and to scientists from other associated laboratories. Gradually, all fusion research activities were integrated at European level.

The current position

The fusion programme, adopted by the European Community Council of Ministers for five-year periods, today covers two types of activity: research done in national laboratories and the JET project.

- ☐ Research in national laboratories is based on association contracts drawn up between Euratom and national research bodies. It is supervised by management committees on which representatives of the two partners sit. Most of the activities carried out in national laboratories in seven Community countries and research centres in Sweden and Switzerland (who joined the Community programme in 1976 and 1979) concentrate on the physics of Tokamaks and Tokamak support activities, particularly magnetic confinement. Other research is going on into alternative processes to the Tokamak.

  In a Tokamak, the deuterium and tritium nuclei are confined in a torus, shaped like a motor car tyre. The technique of magnetic confinement is also practiced in Stellarators and other toroidal-type machines, such as reversed field pinches, which 'strangle' the plasma to confine and heat it. Finally, inertial confinement, using laser technology is being studied, particularly in Germany and Italy. This will enable the Community to keep pace with progress in this field going on outside Europe.

The financial contribution of Euratom covers about 25% of the associations' running costs, rising to as much as 45% for investment in projects of prime importance at Community level. Euratom has assigned about 100 European scientists to its fusion programme, for the most part employed in associated laboratories, which between them have a staff of between 3 500 and 4 000, including about 1 000 researchers. Euratom's mobility allowances cover displacement costs for researchers whose work requires them to spend a limited period in a laboratory elsewhere in the Community.

☐ The JET (Joint European Torus) project, which is assuming an increasingly important role in the Community's programme, began on 1 June 1978, on the basis of Articles 45 and 51 of the Euratom Treaty. Its purpose is to build and run the biggest Tokamak in Europe, currently being constructed at Culham, near Oxford (United Kingdom). The encouraging results obtained by associated laboratories from several relatively small Tokamaks have prompted the building of a larger version. Its main aim is to obtain and study plasma in conditions and on a scale close to that of a thermonuclear reactor. This objective calls for studies in four key sectors:

- the behaviour of plasma in operating conditions similar to those of a reactor;
- the interaction between plasma and the reactor wall;
- the heating of the plasma;
- the production and confinement of alpha particles and the resultant plasma heating.

While the construction phase is scheduled to end in mid-1983, the operating stage of JET will last for five to seven years. The programme and equipment will be sufficiently flexible to allow a gradual development of the installation in line with progress in research studies.

The budget allotted to the JET project is 80% financed by Euratom, 10% by the United Kingdom Atomic Energy Authority (as the host country) and 10% by national organizations associated to Euratom's fusion programme.

Consideration is already being given to the next step, post-JET. The first exploratory studies for NET (Next European Torus) began at Community level in 1978. Up to the end of 1981 however, the major part of this effort was devoted to European participation in the definition of INTOR (International Tokamak Reactor) under the auspices of the International Atomic Energy Agency. A small group of American, European, Japanese and Soviet scientists, supported very effectively by their respective fusion programmes, have met periodically in Vienna since the end of 1978 to define the reactor that will follow the JET-type Tokamaks. The aim of major projects like NET and INTOR is to prove the technological feasibility of the fusion process, once the physical possibility of the process has been established by JET and other installations of the same type. A third generation of projects will be necessary beyond this to demonstrate the industrial and commercial feasibility of fusion.

A new programme

Thermonuclear fusion is currently in a transitional phase between basic research and technological development. To what extent should study be re-directed and, when necessary, where should it be intensified? To answer this question, the European Commission set up a Fusion Review Panel in November 1980. This *ad hoc* group of 11 scientists, chaired by Professor K.H. Beckurts (Vice-President of Siemens AG) was given the task of evaluating the importance of fusion as an energy source for the Community and formulate, in line with projects already underway, recommendations on future policy and action. The group completed its work in June 1981. Its final report is broadly positive; it stresses that Europe must remain in the forefront of fusion research and that it must demonstrate the technical feasibility of nuclear fusion. The group's main recommendations were:

☐ to implement the JET project as fully as possible;

☐ to launch a fusion technology programme centred around NET, solving the problems it poses and speeding up its conception and planning;

☐ to continue the concentration of research on new larger-scale Tokamaks in the associated laboratories;

☐ to implement new projects into alternative devices to the Tokamak (Stellarators, reversed field pinches, etc.) also based on the principle of magnetic fields, without abandoning smaller-scale research into inertial confinement;

☐ to develop international cooperation with all other fusion programmes in the world. The experts want to see continued cooperation in INTOR. They particularly recommend strengthened cooperation with the US fusion programme (currently the most advanced), especially in alternative confinement systems to the Tokamak.

The European Commission based the new programme which will be implemented during 1982-86 on these recommendations. This programme, with a Community financial contribution of 620 million ECU ([1]), will in part replace and in part extend the 1979-83 programme worth 385.5 million ECU. The increase in real terms in the fusion budget was recommended by the experts' group, who felt that a level of expenditure corresponding to 'about 0.6% of total European research and development spending and 0.3% of expenditure on energy imports is justified given the long-term potential importance which this programme represents for Europe's energy supply and given the scientific merits of the programme and its stimulating effect on European industry'. This budget, adds the report, is still more modest *per capita* than that of either the US or Japan. But it should be sufficient to keep Europe on course and assure it a position from which it can negotiate cooperation and information exchange agreements with its partners, which will become more difficult once fusion has entered the industrial phase.

([1]) 1 ECU (European currency unit) = about £ 0.97, Ir. £ 0.69 or $ 1.03 (at exchange rates current on 18 May 1982).

Three major fields of action, each with its own specific financial and technical characteristics, have been defined in the new programme: the JET programme, NET and the 'next step' technology and other activities at associated laboratories. In addition, there are added management and mobility costs.

☐ The five-year JET programme involves three closely-linked phases:

- to April 1983, the completion of construction, so that JET can begin basic operations;

- from January 1982 to June 1987, the progressive siting of additional equipment which will enable JET to begin wider performance, in particular, to develop its plasma heating capability;

- from April 1983 to the end of 1986, the operational phase, which will require extra personnel (up to a total of 480 staff, including 165 assigned from Euratom) and extra finance to meet maintenance and operating costs and massive electricity bills.

The overall cost for the period 1982-86 is estimated at around 400 million ECU, of which 310 million, or 80%, will be financed from the Community budget.

☐ Activities carried out under association contracts will continue to concentrate mainly on Tokamak physics and support activities for Tokamaks, including an increase in aid to JET and NET. The national laboratories will also continue their studies on alternative confinement devices to the Tokamak.

- The five main Tokamaks at present in operation in the associated laboratories will continue to be exploited with improved diagnostic methods to widen the understanding of Tokamak physics and the interaction between the plasma and the reactor wall. In addition, three specialized Tokamaks will be built to study the physics of long pulses, plasma confinement time and the dynamics of impurities produced inside the reactor. These machines should also enable hydrogen plasmas to be produced with similar densities and temperatures as those required in a thermonuclear reactor.

- The laboratories will also continue development of systems for heating the plasma by injections of hydrogen and deuterium nuclei at very high power (several megawatts). This study will be useful for the JET project and other planned large devices. The associated laboratories will develop their research into diagnostic techniques and will provide personnel for the JET programme at a suitable time.

- The uncertainties which still hang over Tokamaks as future 'prototype' fusion reactors call for continued research into possible alternative systems, such as Stellarators, reversed field pinches (10 to 15% of the total budget) and inertial confinement (2% of the total budget).

☐ On the 'next step' and more precisely, NET, which is to take over from JET, the extent and complexity of the studies required call for substantial degrees of competence in plasma physics and several other branches of engineering. A team of about 50 is planned. The Commission plans to involve industry at an early stage, both to benefit from its experience and to deepen companies' knowledge of fusion. In addition, five key research and development areas in 'next step' reactor technology have been specifically identified for the Tokamak device and will be assigned to associated laboratories and the Community's Joint Research Centre: tritium technology; the technology of fertile layers (the lithium 'blanket' which generates tritium); the technology of super-conducting magnets; the development of alloys for building the reactor wall; and methods of remote maintenance.

☐ Mobility contracts, which allow the exchange of researchers between different participating organizations will be widened to cover personnel from industry.

Over 100 Euratom scientists will participate in the programme run by the associated laboratories and in the 'next step'. During these five years, the Community will spend 301 million ECU, on these programmes and on mobility contracts. The Community will contribute 25% towards the general expenses of the associations, 45% towards priority projects and up to 100% for certain projects involving NET.

△

Thus, in a sector of future growth, where major uncertainties still exist, European researchers are participating in one of the greatest scientific adventures of our time. Up to now, thanks to this joint effort, Europe is in the forefront of research and development. It is an example which deserves consideration and which could well provide inspiration for the future ■

The contents of this publication do not necessarily reflect the official views of the institutions of the Community.

Commission of the European Communities

Information offices (countries fully or partially English speaking*)

Ireland	39 Molesworth Street, Dublin 2 – Tel. 71 22 44
United Kingdom	20 Kensington Palace Gardens, London W8 4QQ – Tel. 727 80 90 – 4 Cathedral Road, Cardiff CF1 9SG – Tel. 37 16 31 – 7 Alva Street, Edinburgh EH2 4PH – Tel. 225 20 58 – Windsor House, 9/15 Bedford Street, Belfast BT2 7 EG – Tel. 40 708
Australia	Capitol Centre, Franklin Street, P.O. Box 609, Manuka 2603, Canberra A.C.T. - Tel. 95-50 00
Canada	Association House (suite 1110), 350 Sparks Street, Ottawa Ont. KIR 7SB – Tel. 238 64 64
USA	2100 M. Street, N.W. Suite 707, Washington D.C. 20037 - USA – Tel. 202-862-9500 – 245 East 47th Street, 1 Dag Hammarskjold Plaza, New York, N.Y. 10017 - USA – Tel. 212-371-3804

* Offices also exist in other countries including all Member States.

Office for Official Publications
of the European Communities
L – 2985 Luxembourg

ISSN 0379-3133

Catalogue number: CC-AD-82-012-EN-C