European Communities

EUROPEAN PARLIAMENT

Working Documents

1981 - 1982

8 March 1982 DOCUMENT 1-1080/81

Report

drawn up on behalf of the Committee on Energy and Research

on the proposal from the Commission of the European Communities to the Council (Doc. 1-433/81) for a decision adopting a research and training programme (1982-1986) in the field of controlled thermonuclear fusion

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English Edition

PE 74.903/fin.

By letter of 24 August 1981 the Council of the European Communities asked the European Parliament to deliver an opinion on a proposal from the Commission of the European Communities for a decision adopting a research and training programme (1982-1986) in the field of controlled thermonuclear fusion.

The President of the European Parliament referred this proposal to the Committee on Energy and Research as the committee responsible and to the Committee on Budgets for an opinion.

On 20 October 1981 the Committee on Energy and Research appointed Mr SASSANO rapporteur.

It considered the draft report at its meetings of 22 September 1981, 27 October 1981, 27 January 1982 and 25 February 1982. At the meeting of 25 February 1982 it unanimously adopted the motion for a resolution and the explanatory statement.

The following took part in the vote: Mrs Walz, chairman; Mr Normanton, vice-chairman; Mr Sassano, rapporteur; Mr Adam, Mr Beazley, Mr Bombard (deputizing for Mr Pattison), Mr Calvez (deputizing for Mr Galland), Mr Flanagan, Mr Karl Fuchs, Mr Kellett-Bowman (deputizing for Sir Peter Vanneck), Mr Ghergo (deputizing for Mr Müller-Hermann), Mr Linkohr, Mrs Lizin, Mr Markopoulos, Mr Meo, Mr Moreland, Mr Phlix, Mr Petronio, Mr Protopapadakis, Mr Rinsche, Mr Rogalla, Mr Sälzer, Mr Seligman, Mr Travaglini (deputizing for Mr Pedini), Mr Veronesi.

The opinion of the Committee on Budgets is attached.

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A.

The Committee on Energy and Research hereby submits to the European Parliament the following amendments and motion for a resolution, together with explanatory statement:

TEXT PROPOSED BY PARLIAMENT	COUNCIL TEXT
PROPOSAL FOR A COUNCIL DECISION	
AMENDMENT N° 1	
Recital N° 2	Recital N° 2
Complete as follows:	Whereas, in view of the considerable efforts needed to reach the application stage of controlled thermonuclear fusion, which could be of benefit to the Community, particularly in the wider context of the security of its long-term energy supplies, the various stages of development of the work hitherto undertaken in this field should continue on a joint basis;
'attaching great importance to the strategy of concentrating effort on the Tokamak line and sizeable effort on two alternative lines in magnetic confinement, the reverse field pinch and stellarators, given a periodic reassessment of the reactor relevance of these lines compared with that of the Tokamak'.	
AMENDMENT N° 2	
Recital N° 3	Recital N° 3
	Whereas the scientific progress achieved in this field in recent years in the Community and the rest of the world illustrates the need, particularly for Tokamak systems, to construct larger and more complex devices and to concentrate in particular on the development of plasma heating techniques
'..., attaching greater importance to experiments relating to ignition with compact devices having a high magnetic field;	

ANNEX

AMENDMENT N° 3

Paragraph 1	Paragraph 1
After the first subparagraph add the following:	1. The subject matter of the programme to be executed shall be: (a) unchanged (b) unchanged (c) unchanged (d) unchanged (e) unchanged (f) unchanged (g) unchanged
The work referred to in (b) must be pursued having regard to progress elsewhere in the world in order to establish a position for mutual technical exchanges whenever cooperation in a larger international framework takes place;	

AMENDMENT N° 4

Add the following new paragraph 5a:

In consultation with the Consultative Committee of the Fusion Programme, the Commission may draw up proposals for the supply of fuel to fusion reactors with particular attention to the definition of the mission of the proposed tritium laboratory;

MOTION FOR A RESOLUTION

embodying the opinion of the European Parliament on the proposal from the Commission of the European Communities to the Council for a decision adopting a research and training programme (1982-1986) in the field of controlled thermonuclear fusion

The European Parliament,

- having regard to the proposal from the Commission of the European Communities to the Council (COM(81) 357 final),
- having been consulted by the Council, (Doc. 1-433/81),
- having regard to the report of the Committee on Energy and Research and the opinion of the Committee on Budgets (Doc. 1-1080/81),
- recognizing the need to safeguard the Community's long-term independence in the field of energy,
- whereas a lasting solution to the energy problem would help to ensure political, social and economic stability for the Community as a whole,
- whereas thermonuclear fusion is one of the few possible solutions which could contribute to the achievement of that objective,
- whereas the extent to which the Community has succeeded in coordinating work in this field is a striking example of collaboration among all the Member States for the attainment of a common objective;
- whereas it is particularly important in an enterprise of this nature that efforts should be made by all the Member States, and whereas the Community dimension of this objective should justify further coordination of activities by all Member States as well as fruitful collaboration between the European Economic Community, the international scientific community and other nations, particularly the United States of America;
- having regard both to the steady progress and results hitherto achieved by the Community in the field of thermonuclear fusion, in particular with Tokamak, as a consequence of which Europe now occupies a leading position in this sector, and to the numerous scientific and technological problems which must still be solved in order to develop and utilize a source of energy based on thermonuclear fusion,

- aware of the increasing volume of financial and human resources necessary for such development,

- whereas it is therefore essential, for the reasons given above, that the utmost priority should be attached to techniques which can provide proof as soon as possible of the scientific feasibility of controlled thermonuclear fusion,

- whereas constant monitoring of the project by the European Parliament is necessary given the considerable financial, scientific and technical risks involved;

- whereas, it is the duty of the European Parliament to request that the controlled thermonuclear fusion programme should be developed as far as possible over the next few years, in order to ensure the possibility of generating electric energy by thermonuclear fusion within as short a period as possible,

1. Applauds the high degree of Community integration achieved in this field by the Commission with the aid of the institutions with which it has been associated;

2. Noted with satisfaction the progress achieved in implementing the fusion programme and that the JET Joint Undertaking is in accordance with the plans submitted when the undertaking was set up in 1978.

3. Endorses the recommendations of the Fusion Review Panel to:

   (a) pursue efforts aimed at proving scientific feasibility;

   (b) pursue the programme following the Tokamak route towards a demonstration reactor, both by completing the first stage of this programme (the JET programme with its extensions) and programmes in support of the Tokamak confinement system;

   (c) continue the studies for the implementation of the second stage of the Tokamak programme (NET) and the technological developments necessary in order to carry out this project;

   (d) continue the studies on alternative confinement systems which may be used in a reactor, preferably in collaboration with fusion programmes carried out in other countries, praticularly in the United States,

   (e) keep under continuous review current and future results of European and world activities, with a view to deciding whether to go ahead with the implementation of the second stage of the programme;

4. Recommends, as regards activities other than JET, and as suggested by the Panel, the pursuit of research and activities relating to other Tokamaks inasmuch as they are fully justified in terms of the strategy of the programme and the search for ever wider international collaboration in this field;

5. Considers, furthermore, that it would be advisable, given the scientific difficulties involved in the fusion process, for the Commission to frequently consult a permanent scientific panel made up of senior experts appointed by the Member States;

6. Considers insufficient, however, the attempts made so far to exploit the possibilities of achieving ignition through small devices with a high magnetic field;

7. Attaches importance to the strategy of concentrating effort not only in the Tokamak line but also a sizeable effort on two alternative lines in magnetic confinement, reverse field pinch and stellerators, provided there is a periodic reassessment of the reactor relevance of these lines compared with that of the Tokamak;

8. Invites the Commission to consider proposals for new or novel experiments not included in the Commission's proposal or in the recommendations of the Fusion Review Panel, so that these may be judged technically against the general objectives of the fusion programme and existing work on the programme, and for future fuel needs;

9. Expresses the hope that during the implementation of the programme the Commission will communicate to Parliament proposals for new or novel experiments not included in its proposal which contribute to the attainment of the programme's objectives;

10. Recommends that the development of the programme should be increasingly geared as far as possible towards industrial participation particularly as regards the solution of technical problems with the aim of speeding up the practical application of future scientific inventions;

11. Calls on the Commission and the Council given the extremely long periods required for development work, to ensure that financing is assured also for other major national projects (such as fast breeders, high temperature reactors) once the existing programme (1982-1986) expires without this involving an unduly heavy burden on the Community budget;

12. Wishes the European Parliament to consider annually to what extent financial and technical adjustments to the programme are necessary;

13. Recommends a further strengthening of international collaboration, in particular with the United States, and the pursuit of cooperation on the INTOR project within the framework of the IAEA;

14. Invites the Commission to make proposals to foster fusion technology by encouraging the mobility of scientific and engineering specialists and through the establishment of a European Institute of Technology;

15. Calls on the Commission to use all the means at its disposal without delay to stimulate public discussion on nuclear fusion and its political, societal and social repercussions;

16. Approves the Commission's proposal for a research and training programme (1982-1986) in the field of controlled thermonuclear fusion, subject to the adoption by the Commission of the European Parliament's amendments, pursuant to Article 119(2) of the EEC Treaty and, having regard to the European Parliament's budgetary powers, calls for the Commission's proposal, thus amended, to be adopted as soon as possible by the Council.

B.

EXPLANATORY STATEMENT

I. INTRODUCTION

1. Energy supply is of central concern to modern economics; there is no need to recite the social and industrial upheavals which have resulted from the various stages in the energy crisis since 1973. Naturally enough, effort has been largely concentrated on finding solutions to the short and medium term, solutions which emphasize the need for massive energy-saving measures, which aim to increase energy supply from conventional non-oil sources and which foresee a growing (if not yet crucial) role for alternative sources of energy such as solar power.

2. In the longer run, i.e. into the next century, some foresee a society much less energy dependent than today. Others point to the benefits an abundant supply of energy can bring. The main candidate to provide such a long-term source of power is nuclear fusion.

3. Fusion is the ultimate form of solar power - it is the reaction that powers the stars (including the sun). Atoms of light elements are fused together under intense heat and pressure to create heavier elements, releasing massive amounts of energy at the same time. The reaction that should be easiest to achieve on earth is the combination of two isotopes of hydrogen, deuterium (D) and tritium (T), to give helium. Herein lies the attraction: the raw materials (deuterium and lithium) are amongst the most abundant on the planet (and the reaction is arranged so that tritium is 'bred' from a blanket of lithium around the reactor core) and the waste product is stable and non-radioactive.

4. A controlled fusion reaction has not yet been achieved. Although hardly ten years passed between exploding the atomic bomb and the commercial use of the equivalent (fission) reaction, thirty years have already passed since the first hydrogen bomb explosion. Commercial use of that (fusion) reaction is still at least twenty years away. The essential technical problem is to generate a very hot plasma (about 100m°C) and to contain or confine it (probably in a complex magnetic field, although other techniques are being tried). Laboratories have not yet managed to achieve simultaneously temperatures and density which are high enough with confinements which are long enough. The hope is that the new generation of machines might get some way towards generating some energy in return for the energy consumed. Later machines would be needed to achieve self-sustaining reactions.

5. The eventual utilization of an energy resource based on nuclear fusion, if it proves possible, will be the result of research and development work undertaken over several decades, in the course of which thousands of physicists and engineers will have had to solve many particularly complex physical and technical problems. Given the extent of the human and financial resources necessary for the achievement of this objective, the task must inevitably involve international collaboration, in particular among all the Member States.

6. The European Community, above all aware of the need to seek solutions safeguarding its energy independence in the long term, and in view of the fact that fusion-based energy constitutes one of the potentially more attractive solutions, has since 1958 pursued a research programme in the field of controlled thermonuclear fusion.

7. The work carried out by Member States engaged in research on fusion has thus been linked with the coordinating action of the Community itself, through both financial contributions and the direct participation of Community officials.

8. The Community dimension of this work is explained by:

   - the scale of the financial and human resources which must be made available;
   - the duration of such activities;
   - the considerable importance attached to this potential source of energy in all the Member States;
   - in the event of success, the opening up of a vast market for European reactors.

9. Furthermore, the coordinating action of the Commission has made it possible to avoid duplication and ensure maximum concentration of the financial resources available. The significant and frequently decisive contribution made by the Community in the field of controlled thermonuclear fusion is illustrated by the substantial progress so far achieved in Europe in the field of plasma physics. This progress has placed European activities in a leading position.

10. The projected strategy for building a demonstration reactor includes, as in the past, the development of devices based on the Tokamak principle. To this end the Community has underway a series of experiments carried out in various Member States with devices of the Tokamak type. As it is still not certain that this type of device will be capable of producing reactors for the generation of electric energy, further research is considered necessary, through international

collaboration, on what are judged to be the most promising alternatives. International cooperation, therefore, should be further stepped up, in particular with the United States and on the INTOR project within the framework of the IAEA.

11. Clearly, much remains to be done before fusion energy can be utilized. This implies an increasing volume of financial and human resources which can and must be supplied by the Community alone. We should bear in mind that research activities on the eventual utilization of a source of energy generated by nuclear fusion will probably be the main technical challenge facing Europe in the coming years - and a challenge from which Europe should not draw back.

12. In addition, the work undertaken in Europe has not been wholly satisfactory as regards the studies of plasma behaviour close to ignition. Your rapporteur considers that these experiments are of the utmost importance, particularly in view of the leading position already occupied by the European Community. They will make it possible to confirm certain theories concerning plasma physics on which current projects are based and the validity of which has yet to be proved.

    The greatest attention should therefore be paid to these experiments and priority given to the development of those techniques which may demonstrate within as short a period as possible the scientific feasibility of controlled thermonuclear fusion by magnetic confinement.

13. When so much needs to be done to achieve a fusion reaction at all, it is difficult to draw up a list of costs and benefits, especially on environmental questions. Because of the energy that has to be supplied, malfunctioning will probably lead to the reaction stopping of its own accord. There should be no highly radioactive waste, and the main problems would seem to be the possibility of a fire in the fuel blanket and the disposal of irradiated parts of the reactor structure. In his paper, 'The social aspects of nuclear power', C.M. Braams suggested that the most concrete conception of a fusion reactor might be characterized as follows:

    (a) a deuterium-tritium reactor,
    (b) based on the Tokamak principle (Tokamak is an acronym in Russian for 'current and magnetic chamber'),
    (c) operated in an electric power station,
    (d) in which careful management of tritium is necessary and where materials which become activated must be safely stored for possible re-use,
    (e) of which the disaster potential could be 100 times less than that of a fission reactor,
    (f) which has no military application,
    (g) which, as far as available raw materials are concerned, is competitive with other nuclear or fossil fuel energy sources, and
    (h) the cost of which will be on the high side.

SECTION II: PROGRESS TOWARDS ACHIEVING FUSION POWER

14. Substantial progress is being made in fusion research. The main line of development concerns machines known as Tokamaks. These are very effective at compressing and confining the plasma (i.e. the gaseous raw materials so hot that their atoms shed their electrons). This property derives from their toroidal form: hence, the Joint European Torus, JET. The application of neutral beam injection has allowed plasma temperatures to be pushed up to around 80°mC. So-called open machines have achieved even higher temperatures but with less success in confining the plasma: new concepts for the magnetic 'mirrors' plugging the ends of the plasma cylinder are being tried. The cylindrical form of such machines would lend itself better to the eventual application of fusion power to the production of electricity. Other techniques such as inertial confinement (in which lasers, for example, bombard a fuel pellet) show promise but are at an earlier stage of their development.

15. It is clear therefore that the pursuit of fusion power is going to take some time - probably at least another twenty years - and is going to be expensive. The 1982-86 programme, on which the Parliament has been consulted, is estimated to cost around 1500 MECU; the Community will contribute around 680 MECU of this total. The USA is spending at a rate about 30% higher than Europe, even excluding its substantial effort on inertial confinement. Japanese expenditure is fast catching up with Europe's. The next generation of machines (after JET) will inevitably be larger and more complex and a prototype power reactor more complex still - it has hardly been necessary yet to tackle many aspects of a practical design which are going to cause severe difficulties in development.

16. The further one progresses in a project the more difficult it is to draw back, the sunk investment is so large. One should therefore be certain about the strength of the long-term commitment to solving what is almost certain to be the major scientific and technical challenge for Europe in the rest of the century. It will certainly be asked if such expenditure is worthwhile, given the progress still to be made. Although it is at present impossible to calculate with any precision the costs and benefits of the development of fusion power, the potential prize (i.e. abundant and economic energy supply with acceptable environmental effects) is so desirable as to justify the massive spending and scientific uncertainty.

SECTION III: STRATEGY

17. The programme on which Parliament has been consulted is in effect the whole of the European effort in the fusion field. There is thus a concentration at Community level of policy making which is probably unmatched in any other sphere apart from agriculture. The programme must thus not only include projects which are desirable in themselves but also have an overall balance and strategy.

18. European effort is heavily concentrated on Tokamak machines; the JET machine being built is the largest of these. Tokamak machines certainly offer the best chance of achieving a self-sustaining fusion reaction. What is less certain is whether this layout will permit the construction of a practical power reactor: the torus is so compact and so surrounded by magnetic field coils that space for the fuel blanket and for devices to abstract the heat may be inadequate.

19. Careful thought therefore has to be given to the ultimate objective of the programme. Is it to press forward as rapidly as possible with the achievement of a self-sustaining reaction, and sort out the practical problems subsequently? Or is it to work more directly, if more slowly, towards a final power reactor?

20. The European effort has hitherto been weak on non-Tokamak approaches to fusion and, despite the Commission's efforts, it has not yet been possible to launch an effective programme in the field of fusion technology. The balance to be drawn between the two objectives will affect the amount of effort which should be devoted or diverted to correcting these weaknesses.

21. The usual difficulty of having a democratic review of large and highly-technical projects is compounded in this case where the programme encompasses virtually the whole European effort on the subject. The Commission has arranged for a report to be made by a group of eminent scientists and engineers familiar with but not associated with the programme. The report of this European Fusion Review Panel discusses the three stages on the road to fusion power, namely:

    scientific feasibility
    technical feasibility
    commercial feasibility

22. The Panel recommended the following strategy for the Community:

- to pursue a substantial programme following the Tokamak route towards a Demonstration Reactor. To complete the first stage of this programme (the JET project with its extensions) and carry out programmes in support of the Tokamak confinement system;

- to pursue the development of the technology required to build the second stage of the Tokamak programme (NET), guided by conceptual design studies;
- to investigate alternative confinement systems with reactor potential preferably in collaboration with other world fusion programmes, in particular the USA programme;
- to review the results of JET and similar experiments being carried out elsewhere towards the end of the 1980's and decide whether to go ahead with the construction of the second stage of the Tokamak programme.

23. The Panel also made the following points:

(a) 'That the relatively narrow approach of the present European programme entails some vulnerability, which is partially offset by international cooperation'.

The US, for example, devotes as much money to inertial confinement as to Tokamaks, together with substantial amounts on mirror machines (20%) and on heating and technology (12%).

The Panel thought JET and NET technology should receive about 80% of the available funding and alternative confinement systems about 15%.

(b) 'Although the plasma physics aspects of the fusion programme are well covered, there is already considerable backlog in the equally important fusion technology programme. In particular, systems aspects related to operation and maintenance have received inadequate attention'.

and

'Although contacts between fusion and fission research and development exist at some laboratories such contacts appear infrequent and insufficient'.

There is no doubt that much greater effort is needed on the so-called 'technology' aspects of the programme. The Commission is right to stress this point.

The involvement of industry would bring considerable expertise and be of benefit in the long term. The Commission's proposal envisages the awarding of various contracts to industry, and this practice should be extended as far as possible. Similarly, the implementation of the proposed 1982-86 programme should make it possible to establish a proper balance between the scientific and technical aspects of the programme.

(c) 'The European effort in inertial confinement studies is small and does not even allow a sufficient evaluation of the work being carried out in other parts of the world'.

Inertial confinement is the only real alternative to magnetic confinement. It is worrying that Europe's position is so weak. Nor is this a field in which there has hitherto been much international collaboration, due to the military applications of some of the technology; this may now be changing. Budgetary constraints rule out a major effort in this area, and the Commission proposal includes a small increase. It may be that more ought to be done.

(d) The Panel also pointed out that tritium handling would be a crucial aspect of fusion technology. The USA was setting up a civilian laboratory dedicated to tritium at Los Alamos. The panel recommended that a test facility be set up in Europe. The Commission proposal appears not to mention this possibility.

(e) The Panel also pointed out that final decisions on the form of the next generation machine (NET) could not be taken until certain experiments involving tritium had been carried out on JET. After some time these will render the load assembly unusable, and are therefore left until last in the experimental programme. There will thus be a gap of several years in the Community's fusion programme. Studies on eliminating this gap are urgently needed, but the Commission proposal appears not to address the problem.

Other observations by the Panel concerning collaboration, management and personnel are included in subsequent sections.

However, the next section of this report considers that part of the programme which can be devoted to the development of experiments intended to demonstrate rapidly the scientific feasibility of controlled thermonuclear fusion using the Tokamak system.

Ignition experients

Scientific justification

24. One of the principal objectives of research programmes relating to controlled thermonuclear fusion is the achievement of so-called ignition conditions in which the temperature of the thermonuclear plasma is self-maintaining without the need for a system of external heating.

The attainment of this objective, in itself of the utmost significance, requires that not merely theoretical but also experimental studies should be made of the behaviour of plasma close to ignition conditions.

Given that the current European programme does not provide for research actions leading to such studies in the near future, your rapporteur endorses the recommendations of the Fusion Review Panel for the pursuit and stepping up of such experiments.

25. Such studies have hitherto been effectively undertaken with devices having a high magnetic field which, thanks to the limited cost of their construction, constitute at present the most promising type.

These devices have been conceived on the lines of toroidal devices which are compact and have a high magnetic field, of which ALCATOR A of the MIT has been a prototype and FT of Frascati and ALCATOR C are the current forms and natural development.

Given the successes achieved so far by the high magnetic field approach, including the current record values of the 'NTE' and 'NET' parameters recently obtained on FT and the even more recent results obtained with ALCATOR, such as those concerning the intensity of the magnetic field, many experts consider it possible to obtain plasmas for thermonuclear use by utilizing techniques which are already partially established.

26. These devices are relatively inexpensive as compared with the so-called large devices which, in terms of their functioning, are largely based on costly techniques for the auxiliary heating of plasma, such as the injection of neutral atoms or heating through radio frequencies, the feasibility of which for high-power transmission remains to be proved.

Objectives of these experiments

27. As stated above, one of the principal objectives of this type of experiment should be to study the plasma in conditions close to those of ignition, or even directly under ignition conditions.

This would make it possible to establish, for example the possibility of utilizing the alpha particles (helium nuclei) produced by the reactions of leuterium tritium fusion for the heating of plasma. Another important objective would be to study the behaviour of plasma when subjected to extremely high magnetic field intensity and current.

In addition, tritium technology could be progressively acquired.

28. In more general terms it will be possible, according to experts working in this sector, to attain a series of significant objectives for thermonuclear plasma physics which are not covered by the current experiments proposed under the European strategy, at least not for the immediate future. In particular:

- study of the transport and laws of scale in collisional systems with thermonuclear implications;
- study of chemical heating and its effective possibilities;
- study of adiabatic compression as a means of reducing the time needed for obtaining plasma systems with thermonuclear implications;
- study of adiabatic compression as a means of multiplying the effect of auxiliary heating applied before actual compression;