EUROPEAN COMMUNITIES

Information R+D

SERIES: RESEARCH AND DEVELOPMENT

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THE JET PROJECT

1) Jet and Fusion

JET (Joint European Torus) is the centrepiece in European Community plans to try to tap a new source of energy. This is FUSION - the source of energy of the sun. Unlike fission, splitting the nuclei of heavy atoms like uranium, fusion involves smelting together light atoms like hydrogen. If fusion can be made to work, major benefits will follow.

In particular there will be no fear that fuel will run out, (as there is with fossil fuels such as oil). The key elements needed for fusion are deuterium and lithium, found throughout the world in virtually inexhaustible quantities.

The road to fusion energy is very long. Most experts believe it will take some decades of work to solve the problem. But there is accord in all Community countries that the prize is well worth pursuing and that existing work on fusion should go ahead. This is where JET comes in, the biggest experiment to date in European fusion research.

2) The Commission's Role and Origins of the JET Project

The Commission has been advancing programmes for common action on fusion since the birth of the European Atomic Energy Community (EURATOM) in 1958*.

Its role has been to coordinate work in different fusion laboratories throughout the member States, to provide additional scientific and technical staff and to make a financial contribution.

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* For details of the fusion programme and of the non-JET fusion research effort, see the information paper "The European Community Programme in Thermonuclear Fusion and Plasma Physics".

JET is a natural outgrowth of these activities. If fusion research is to advance then JET must be built. Yet the project will be of such size and cost that no member State could easily meet the requirements on its own. Hence JET is ideal for a Community effort.

With this in mind a Working Group was formed in 1971 which prepared various concepts for JET and compared technology and cost. On the basis of the group's results and on a proposal of the Commission, the Council of the European Communities agreed in 1973 that a Project Team be established to design JET. This team, made up of experts from the laboratories of all member States, was quickly assembled and hosted at the Culham Laboratory, England. It produced its final design proposal in 1975 - including detailed cost estimates and planning schedules.

3) Why JET must be built

A fundamental problem of fusion is that the pairs of nuclei in the elements forming the fuel naturally repel one another. Fusion can only occur if the nuclei are hurled at one another with great energy. To produce these collisions the fuel must be heated to temperatures of 100 million degrees and more. Such temperature means the fuel becomes a special kind of gas called a PLASMA. It also means that no normal container could hold the plasma. Its walls would melt and the plasma would cool down.

Fortunately the plasma is not composed of neutral atoms but of electrically charged particles (electrons and ions) which are subject to the action of magnetic fields. This makes possible the confinement of plasmas in "magnetic containers".

Scientists have long been probing how magnetic fields could be used to keep the plasma together and stop it from touching the container walls. Many models have been tried. In the last five years research in Europe concentrated on the so-called "closed configuration" system in which the plasma is kept in a doughnut-shaped vessel called a TORUS. The Soviet Union had been working on the "closed configuration" system called TOKAMAK since the early 1960's and had achieved the first good results. Several Tokamak devices have been built in the associated laboratories of the Community Fusion Programme and performances have been largely improved. The limit had been reached at which

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performances cannot be further improved without building a much larger Tokamak than the present generation ones. JET will be a large-scale Tokamak.

4) Why JET is a large Device

The aim of JET is essentially to produce and to study a plasma in conditions as close as possible to those needed in a thermonuclear reactor. In such a reactor fusion reactions should of course produce more energy than is spent to heat the plasma. This is possible if the density of the plasma is sufficiently high and the time during which it is kept burning inside its magnetic container is sufficiently long. Now magnetic containers are not absolutely impermeable to the plasma: it diffuses through the "magnetic wall" of the container so that its density decreases and the time during which it is kept burning is reduced. In order to limit this diffusion effect, the "magnetic wall" must be made as "thick" as possible. This means that the magnetic field must occupy a large volume. The present generation tokamaks are too small to prevent to a sufficient extent the diffusion of the plasma through its magnetic container. This is one of the reasons why their performances are limited and the construction of a larger device such as JET is necessary.

Another reason of building a large device is connected with a self-heating effect of the burning fuel in a thermonuclear reactor: fusion reactions between deuterium and tritium produce both fast neutrons (14 MeV), which carry a large amount of useful energy, and energetic charged particles (3,5 MeV alpha-particles) which contribute to heat the fuel itself and keep it burning. In order to be able to heat the fuel, these charged particles must also be kept within the magnetic container. Since they are highly energetic a large magnetic container is needed to confine them.

5) Some Information on the JET Device

As in all Tokamaks, the plasma of JET is ring-shaped and is produced in a torus-shaped vacuum vessel. It is confined by a magnetic field which is the combination of the toroidal field produced by a set of toroidal field coils which link the torus, and the weaker poloidal field produced by the current flowing in the plasma.

This plasma current is induced by a transformer, of which the plasma is the secondary winding. The primary winding of the transformer and the subsidiary equilibrium coils, which give the fine control of the position and shape of the plasma, are called poloidal field coils. The current induced in the plasma plays also the important role of heating the plasma by ohmic effect. This heating is however not sufficient to bring the plasma to the high temperatures envisaged. Additional heating methods will therefore be applied.

The following is some general information on the components of JET:

- The vacuum vessel (torus) is made of eight stainless steel sections, which are welded together. The total weight is 80 tons.
- There are 32 toroidal field coils made of copper and cooled by circulating water, total weight 380 tons.
- The poloidal field coils are also constructed of water-cooled copper, total weight 80 tons. The transformer efficiency is improved by an eight-limbed iron core, weight 1500 tons.
- The power supplies are a combination of power from the network and motor-generator-flywheel sets. The maximum power drawn from the supplies will exceed 500 mega watts.
- Additional heating will be provided by injection of energetic neutral atoms into the plasma, by radio frequency heating and by adiabatic compression of the plasma obtained by increasing the magnetic field.
- The device will be operated by means of a centralized control system.
- The temperature, the density and other parameters of the plasma are measured by special techniques called "diagnostics".
- The control circuit and diagnostics will be linked by computers which will provide fast feedback control of the plasma and apparatus and will assist in analysis of the measurements for the interpretation of experimental results.

6) What JET will do

With JET, scientists will be able to study plasma in conditions much closer than hitherto possible to those needed in a thermonuclear reactor. They will see how plasma behaves in these conditions and how it interacts with the wall of the container. They will develop and test different methods of heating the plasma to temperatures at which thermonuclear fusion reactions can take place. All these experiments will be performed with a plasma which will not contain the elements necessary to produce fusion reactions. Finally, if these experiments are successful, a plasma will be produced with a deuterium-tritium mixture and thermonuclear fusion reactions will be observed.

The results will show whether the right road is being taken to harness fusion energy.

It is worth noting that there are three other projects in the world which can be compared with JET. One is bigger - the Soviet T-20. Two have a smaller volume but a higher magnetic field than JET. They are the TFTR in the United States and the JT-60 in Japan. A successful completion of these projects does not mean that a fusion reactor is just around the corner. Even if JET should yield the best possible results at least two more complex and costly stages will be needed before fusion energy becomes a reality. It could well be a competitive energy source in the early 21st century.

7) JET's Cost, Organization and Management

Following the report of the JET design team, the Commission proposed that JET construction go ahead in the Community's fourth five-year fusion programme (1976-1980). The proposed expenditure on JET during this period is of 135 million units of account* at March 1975 prices. (See Annex 1 for budget details).

The management structure of the JET project has been agreed by all partners and would be as follows:

- A JET COUNCIL to meet at high level once or twice a year to advise on overall general management. Its members shall be as follows: Belgium one, Commission two, Denmark one, France two, Germany two, Britain two, Italy two, Netherlands one, Luxemburg one, Ireland one, Sweden one. Its decisions shall be taken by a two thirds majority.

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* One unit of account (ua) equalling 50 Belgian francs

- A JET MANAGEMENT COMMITTEE to meet about once a month. It includes one member for each country participating in the project and one for the Commission. Its responsibilities will include review and approval of the project development plan, proposals on annual budget and staff, deciding on award of contracts above 50.000 ua, etc.

- A HEAD OF PROJECT shall be responsible for directing the execution of the project. He will be assisted by senior managers appointed by the Management Committee on his proposal.

- THE JET PROJECT TEAM. A multi-national team of 200-300 people. About one third of these should come from the host site, another third from the laboratories of the associations and one third from industries taking part in JET's construction.

8) Independent Assessment of the JET Project

Because of the size, complexity and cost of JET, the Commission and the member States agreed a wholly independent appraisal of the project should be sought. This job was given in May 1975 to the Engineering Division of the Reactor Group of the United Kingdom Atomic Energy Authority. This team, called the indemendent Assessment Team (IAT), produced a report discussing in detail all the elements of the project.

A final consultation took place between the JET team and the IAT in April 1976 and the degree of agreement between the two parties was most satisfactory.

This has not been the only check carried out into JET.
A Consultative Commitee for Fusion (CCF) composed of high level officials of the Governments participating in the Fusion Programme has been recently set up to advise the Commission on the programme, in the frame of nuclear and energy research policy. The CCF discussed at the Commission's request in April and May 1976 the scientific objectives, technical and financial aspects and management problems of the JET project. In its unanimously adopted opinion, the CCF:

- said the size of the JET device was in accordance with the objectives i.e. plasma study in dimensions approaching those of a thermonuclear reactor,
- commended the Commission and the JET team for arranging an independent assessment. The results gave confidence JET could be built and operated as planned,

- accepted the cost of five-year construction as 135 million units of account at March 1975 prices,

- recommended the Commission to create the JET Council and Management Committee and to ask the partners to nominate members,

- strongly recommended the realisation of JET and urged the Council of Ministers to take all necessary decisions as early as possible.

9) Current Status of Project and JET Site

There is thus unanimous accord on the value of the JET project. Much care has been taken to define clearly the aims of the project and crosscheck the means proposed to achieve them. Why then is JET at present (June 1976) not being built?

The answer is that there is no agreement in the Council of Ministers on where to put it.

In 1974 a Site Committee was set up: composed of members nominated by Fusion laboratories in member states chaired by a Commission representative and assisted by experts from the JET design team. This body held eight meetings between April 1974, and February 1975. In May 1974, it sent a questionnaire on site requirements to each partner and in September had before it the candidature of the following possible sites:

- CADARACHE in FRANCE
  JÜLICH and GARCHING in GERMANY
  ISPRA, an establishment of the Community Joint Research Centre in ITALY
  MOL in BELGIUM.

The Committee visited the six candidate sites in December 1974, and four sub-groups from its own ranks studied these specific questions at each place:

a. Electrical Power Supplies
b. Problems connected with safety
c. Supporting facilities (technical support, computers, availability of buildings, library, etc.)
d. Existence of social conditions for a multi-national staff with families (including education, housing, leisure, climate, closeness of towns, ease of receiving visitors etc.).

In February 1975, the Site Committee sent its final report to the partners who all underlined the quality and objectivity of the Committee's work.

The findings of the Committee led to the conclusion that Ispra is the most suitable site.

At the Council's meeting on December 15th 1975, divergent views on siting of JET where expressed although generally favourable to the development of the fusion programme and to the construction of JET, the Council was unable to reach an agreement on the problem of the site and therefore did not approve either the programme or the JET project.

At its meeting on February 24th 1976, the Council failed again to take a position on the site and did not approve the JET project. However, it passed an overall budget for the Community programme (with the exception of JET) of 124 million units of account for the five years 1976-1980. But it provisionally restricted implementation of this programme to 1976 (with an appropriation of 20.8 million units of account) pending a final decision on JET. A further Council meeting (Research Ministers) was agreed for June 18th but did not take place.

At its meeting on July 19th and 20th 1976, the Council (Foreign Affairs Ministers) made the following declaration:

"The Council had proceeded to an exchange of views on the JET research programme, relative to controlled thermonuclear fusion. It has adopted a favourable opinion on the rapid undertaking of this enterprise within the framework of the pluriannual Research and Education Programme (1976-1980) of the Community; the necessary decisions will be submitted to the next Council of Research Ministers."

This declaration has provided a new impuls. The fusion scientists can regain confidence in the project. Doubts about the determination of the Community to carry out the project have been dispelled.

A programme decision has, however, still to be reached. The Research Council will again meet in October. That will have to bear in mind that, unless a concrete decision is reached, the JET project would lose its competitivity with the comparable projects of the United States, the Soviet Union and Japan.

ANNEX 1

TYPE OF EXPENDITURE (1)	Amount (Mua)
THE JET DEVICE (comprising mechanical structure, Toroidal field magnet, Core and outer coil support structure, Poloidal field windings, Vacuum vessel, Limiter, Miscellaneous, Spares, Transport)	29.1
AUXILIARY SYSTEMS (comprising Pumping and Cooling systems, Assembly and Maintenance systems, Additional Heating systems	9.0
POWER SUPPLIES (for Toroidal and Poloidal field systems, Auxiliary power supplies)	22.5
CONTROL, MONITORING, DATA ACQUISITION (comprising Computers and peripherals, Control station and connections	3.5
DIAGNOSTICS	3.5
OPERATING BUDGET (Preparation of the operation phase, Test and commissioning of the device, Provision for modifications)	8.9
BUILDINGS (Assembly hall and Torus hall, Power supplies areas, Cooling tower, Rental auxiliary buildings)	15.3
MANPOWER (Team for construction phase and preparation of operation phase, Overheads, Travel)	31.9
RESERVE	11.3
	135

(1) Budget established in March 1975, starting from national currencies and converting to Belgian francs, 1 ua equals 50 BF