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EUROPEAN ATOMIC ENERGY COMMUNITY - EURATOM

EURATOM'S RESEARCH ACTIVITIES
AN ILLUSTRATION : THE ORGEL PROGRAM

by
J. Guéron - J.C. Leny

1962

Paper presented at
the Nuclear Congress - New York - U.S.A.
June 4-7 , 1962

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Brussels, November 1962-pages 23 + figures 4

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These actions are carried out in three Common Research Centers, at Ispra (Italy), Petten (The Netherlands) and Geel (Belgium). Some of these actions are managed from Brussels, which is the case for the ORGEL Program. Besides the research work performed in the Research Centers numerous and important research and design contracts are performed in the member countries, a large number of which is linked with the U.S.-EURATOM agreement.

Further EURATOM participates also in the construction of industrial nuclear power plants, by contributing to funds, management and working teams.

Finally, in the frame of the O.E.C.D., EURATOM joined the HALDEN and DRAGON projects on behalf of the Six.

The objectives of the ORGEL Program are outlined in details.

A list of the various research stages is given as well as the various research facilities. In particular, the ECO critical experiment, the EXPO exponential experiment, now under construction at ISPRA, and the ESSOR reactor, now in the detailed design phase, are mentioned.

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An illustration : the ORGEL Program

SUMMARY

According to the provisions of the Euratom Treaty, EURATOM aims at helping national programs and at carrying out independant actions which are not included in the national plans and which enable EURATOM to support its judgment.

These actions are carried out in three Common Research Centers, at Ispra (Italy) Petten (The Netherlands) and Geel (Belgium). Some of these actions are managed from Brussels, which is the case for the ORGEL Program. Besides the research work performed in the Research Centers numerous and important research and design contracts are performed in the member countries, a large number of which is linked with the U.S.-EURATOM agreement.

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I. EURATOM's TASKS AND GOALS

Since EURATOM came into being, somewhat over four years ago, two significant sets of facts have occurred in atomic energy in the European Community.

First, the national atomic programs of the Six have progressed. Research establishments have been finished and have assumed full activity, or continued their work. Some industrial action has developed, both in design and in manufacturing. Some reactors have been completed and have started operation. But these are all test reactors or reactor experiments. None of them deserves to be considered as industrial machines, or even as prototypes, in the true meaning of the word. However, the construction of a few such machines has continued, or has been started, during the period under review.

This, of course, stems from the well-known comfortable situation of the conventional power industry. But also - and specially when taken together with the delays and troubles which befell the experimental machines - this emphasizes the youth and immaturity of atomic development and the magnitude and diversity of problems which must be solved to create a new big industry when, not only new machines but new materials and new safety problems, must be studied, mastered and reduced to manufacturing and operating conditions all at once.

Second, the Community has become a reality and, as a scientific and technical working organization, it has overcome its worst teething troubles.

EURATOM is now finishing its first program and discussing its proposals for the next five years with the national authorities of the Six. This is, therefore, a convenient time to summarize what we have done, explain why we did it so, and state what we we want to do and how.

By the end of the year, we shall have committed practically all the money which the Treaty has stipulated for us, namely 215 million $. As, for various reasons, the preparatory and build-up periods have lasted over 2 years of the five, it means that this spending will have taken place mostly in 2.1/2 years, starting in mid 1960.

While this is a great amount of public money, let us not forget that it is well under one fourth of what the member states will have spent on similar activities during the same time. And this ratio takes added significance when we remember that the atomic business is widely different from one country to another.

According to the provisions of the EURATOM Treaty, which happen to coincide with those of common sense, EURATOM has, on one side, helped national programs, and, on the other, carried out independent actions.

These latter are unavoidable for two reasons. First, many things need doing, which are not included in the national plans and EURATOM is doing some of them - not all, by far. Second, it is not possible to wisely and efficiently help, advise, or associate with, national activities without possessing independent means of action and of judgment.

EURATOM's own action is carried out in, and through, the establishments of the Common Research Centre. There are four such establishments : the main one is at Ispra (Italy); another one will start at Petten (Netherlands); the third, at Geel (Belgium) is the Bureau of Nuclear Standards, and the fourth, at Karlsruhe, now building, will be the "European Institute for Transuranium Elements". The names of the last two explain clearly what they are destined to do.

The first two are described as "general competence establishments". This means that they should be able to do all sorts of things in atomic energy, but it does not imply that they have licence to do anything. In fact, EURATOM aims at clear-cut programs.

In addition, some projects - and this is being the case for ORGEL - are managed from Brussels by assistants to the General Director of the Research and Training Division, together with a minimum staff and with the help of the establishments.

A fundamental character of EURATOM's establishments is that they are based on previously existing national centres. This was imperative for many reasons, namely :

(a) it emphasizes the fact that the Community is not distinct from the member countries;
(b) it saves time;
(c) above all, it creates EURATOM's own means without adding to the dispersion which is, to our judgment, a great drawback to the development of independent atomic energy in Europe as compared with the situation in the other great atomic powers.

Ispra possesses important computing machines (digital and analogue) : one IBM 7090, two IBMs 1620, many PACE analogue computers which are needed for reactor work. But they are also used for computations asked for by the other communities, by national centres and industries. And they serve also an independent research program in automatic translation and automatic documentation.

The first derives from the Babel situation in the world, where the need for a common vehicular language has not yet been recognized and cared for. The second is a necessity in front of the exponential increase of the factual capital of science and technology.

The main center of interest for Ispra is the development of the "ORGEL" type of reactors. These use natural uranium for fuel (in the form of ceramic compounds, perhaps even of alloys), heavy water as moderator, high boiling, organic compounds as heat transfer medium, and special preparations of light metals as structural components. This combination holds reasonable promise of industrial future. At the same time it can profit from, and contribute to, the development of other heavy water reactors developed on the national level. Further information on this project is given in Part II of this paper.

It is important to emphasize that the main departments in Ispra (reactor physics, materials, engineering) are for the time being mainly or wholly engaged in ORGEL problems. The work, coordinated by a project leader and his staff, gives rise, in addition, to numerous and important research contracts placed in the member countries.

ORGEL is also the occasion for very active cooperation with American and Canadian laboratories.

A great fraction of EURATOM's funds (over the third) are spent outside its own establishments [x], but these outside spendings never take the character of grants. Giving grants is the business of numerous national and international organizations. While this is an efficient and valuable method of promoting and orienting research, it is not EURATOM's.

EURATOM deals either through definite research contracts, through associations aiming at wide objectives, and through the power reactors participation scheme.

(x) In addition to this, one must, of course, count the important development and construction contracts placed by the establishments themselves.

The main body of research contracts is linked with the US-EURATOM agreement. This aims at the construction in Europe of American type reactors, it being understood that European industry must take the greatest possible share in construction as well as in related research and development work. However, part of the research and development is to be carried out in America. The EURATOM Commission pays for work in Europe : the A.E.C. pays for work in the U.S.; the amounts are to balance at the end. Decisions on the projects to select are taken by a joint US-EURATOM board; results are open without restriction to both parties.

So far, 94 Research & Development contracts have been so placed, most of them in the Community. They deal with problems related to water reactors, and mainly concern fuel elements, reactor tank construction, special materials, fuel chemical processing, recycling of plutonium, waste treatment.

In addition to good quality research in Europe - and to the construction of one boiling and one pressurized water reactor - this agreement has led to the increase of intimate relationship between European and American laboratories.

The general condition of the power industry, alluded to above, has led the Commission to recognize that, in order to promote in good time a European nuclear industry, incentives are now necessary for the building of nuclear reactors. The participation program is, therefore, open to electricity producers who intend to build industrial nuclear plants - good enough and big enough plants - and we accept to share completely the know-how so obtained with others, under the aegis of the Commission. The Commission contributes moderate amounts towards various expenses which will help establish European industries. Three reactors have been so far accepted in this framework (one graphite-gas cooled; one boiling water; one pressurized water).

The associations are created when, for long term research, the Commission finds national projects which can usefully be extended. This is done in the following way : the national undertaking is transformed into a joint operation in which the two parties contribute to funds, to management and to working teams.

The associations cover the following fields :

Thermonuclear (fusion) processes

Nearly all non-military research in this field is or will soon be included in EURATOM associations. It is already so in France and Italy, partly in Germany. Another German association and one in the Netherlands are in the making. Belgium has found it sufficient to send good scientists in our associations.

Fast reactors

We can hope for a similar consolidation of all Community work, in the near future, in the most important field of fast neutron breeder reactors. An association with the French C.E.A. (Atomic Energy Commissariat) is nearly ready; negociations are getting under way with Germany. Such a consolidation will, of course, help to establish and increase collaboration with the U.S.A. and U.K. in this field.

High flux reactors

The most modern of such reactors in Europe, BR-2 in Mol, is run by association between EURATOM and the Belgian C.E.N. (Centre d'Etudes Nucléaires).

Miscellaneous

Homogeneous reactors, some nuclear physics, applied radiobiology in agriculture and in animal studies, as well as isotopic geology, have given occasion for other associations with French, Belgian, Dutch and Italian organizations. Some exist also (in particular in Germany) in the most controversial field of nuclear merchant ships.

O.E.C.D. undertakings

The HALDEN and the DRAGON O.E.C.D. projects (in which the Commission has joined on behalf of the Six) can be considered as associations because these projects, like EURATOM's associations, are characterized by a national start followed by joint financing, joint management and international teams.

The HALDEN project (in Norway) concerns a modest reactor experiment on boiling heavy water reactors.

The DRAGON project is an important development towards high temperature, gas-cooled reactors. It derives from a British project. It should logically be linked with the BBC/KRUPP AVR undertaking. This is another association which EURATOM has been looking to - for well over three years now - and which has been recently accepted by the German authorities.

x x
x

It is now rather easy to figure out what the second five year plan must look like. Its three main features are :

(a) active furthering of actions already in hand;
(b) within the minimum healthy rate of growth;
(c) with just enough leeway to maintain a sensible measure of exploration in new fields.

Both a global approach and an item-by-item reckoning lead to total appropriations of 480 million $ in the five years 1963 to 1967. At the same time, the staff numbers should progress from somewhat over 1900 to over 3500 with an average number under 3000.

No new establishment of the Common Research Centre should be created; those already in existence should reach a rather steady condition of activity.

The main lines of reactors to be developed should be those already defined, namely :

(a) "ORGEL", mostly by our own work in Ispra and by contracts;
(b) fast reactors, using plutonium as fuel, mainly by association contracts, gathering the forces of the Community in the national projects already under way;
(c) high temperature gas-cooled reactors, again by the development of existing or new associations.

Accessorily, other industrial reactor types will be considered or contributed to :

(a) The Research & Development program already under way in the framework of the US-EURATOM agreement should be continued and adapted to industrial and technical circumstances as they develop.
(b) Variants of reactor types can be usefully worked on without involving the same sort of expense on the setting-up of an entirely new family (that is up to 400 million $ from first experiment to really industrial models). Nevertheless, one must be very careful - perhaps all the more careful - in embarking on such work. This is why development of ordinary water, or heavy water reactors, such as integral superheat or spectral shift, or fog cooling, must not be entered into without full consideration. Some development work in these lines is useful and non-committing.

So called reference designs and/or economic studies can be very badly misleading when, as is too often the case, they are based on insufficient nuclear and engineering data.

Most likely any such operations would be of a definite industrial character. They would therefore go beyond the Commission's research program. But they might be dealt with as "common enterprises" as defined in Chapter V of the Treaty, and they might need a Research & Development program in which the Commission could take an active interest.

x x

x

We should keep alert and informed in some sidelines which may assume importance in the future, so as to be ready to get into action when needed. The auxiliary power sources for space probes for instance, fall naturally in the field of the Karlsruhe Transuranium Elements Institute from the chemical point of view, and, from the physics one, is that of the direct conversion group of Ispra.

Our interest in high temperature reactors may lead into the very high temperature machines which are considered for space propulsion.

When member nations decide to get together for their endeavors in space, it might be considered logical, and appropriate, that they entrust to an already existing and competent Community the relevant nuclear parts of such programs.

Without going into details, the following must be mentionned for the sake of completeness :

(a) thermonuclear work will go on;
(b) activity will be maintained in the various chemistry fields associated with atomic energy, from fuel processing to waste products treatment and disposal, and to isotope applications;

(c) in addition to the regulatory role entrusted by the Treaty to the Commission in matters of safety and public health, research relevant to these problems will be maintained.
From this stems a biology program which, prepared and began in the last eighteen months, should go into regular steady operation during the second five year period. Here again, we shall mostly work by association with national institutions.

II. THE ORGEL REACTOR

As stated in Part I of this paper, ORGEL represents one of EURATOM's own actions. It is aimed at the development of a European power reactor system, i.e. :

1) which can be operated in Europe without any outside help; the need for enrichment, if it is not ruled out in every case, is however not necessary (it is not a "sine qua non" condition).
   As regards heavy water, a certain production capacity could be rapidly built up in Europe if necessary.

2) which would utilize the united resources of the six Community countries. The problem here is not only of creating a spirit of personal cooperation, but also - which is more difficult - of inducing commercial firms to work in collaboration.
   We have, however, already had some success in two major projects :
   a) the ESSOR (ESSai ORgel) reactor design study being carried out by a Franco-German group made up of the firms Groupement Atomique Alsacienne Atlantique (G.A.A.A.), France, and Internationale Atomreaktorbau G.m.b.H. (INTERATOM), Germany.
   b) the study for the ORGEL reference project, aimed at the complete design of a 250 MWe plant, on which an economic evaluation of the project could be based (determination of cost functions, etc.), is now being carried out by a group consisting of the firms BELGONUCLEAIRE (Belgium), INDATOM (France) and SIEMENS-SCHUCKERTWERKE (Germany).

   However, we do not intend to stop here. Quite apart from the other EURATOM activities, where the same policy is being pursued as far as possible, the aim of the ORGEL project is to enable European industry to construct reactors of this type with the aid of the research and development infrastructure set up by EURATOM in its Joint Research Centre or by means of contracts with the Community's public or private laboratories.

3) which could be incorporated in the various national programs as harmoniously as possible, at the same time avoiding useless duplication of effort. In this way, the heavy water lattice study supplements the projects undertaken in Germany and France, thus providing for advantages to be derived by both sides. The organic coolant studies will make a marked contribution to the organic programs now in progress in Italy and Germany. These programs will likewise benefit from the research being carried out on a fuel (uranium carbide or uranium metal) and a structural material (SAP).

Resources available

It is worthwhile remembering that the date on which the project commenced was very near January 1, 1960. Since the agreement handing over the Ispra Centre to the Commission was ratified in July, 1960, the date at which the Ispra services and departments began participating in the ORGEL project can be fixed at approximately January 1, 1961.

Our first goal was to design an infrastructure with a view to investigating interesting reactor solutions. Studies are being carried out by EURATOM's scientific departments and by contracts with laboratories or industrial concerns in the Community. These contracts are being executed under the supervision of the Commission's scientific departments either in Ispra of in Brussels headquarters (which is the case of optimization, economy and dimensioning studies as well as the ESSOR design studies), or in other EURATOM centres.

The following table describes the project's various research phases :

ORGEL PROJECT

I. PROJECT COORDINATION	II. RESEARCH & DEVELOPMENT PROGRAM
- Coordination of scientific and technical activities. - Orientation, economy, dimensioning and optimization studies, etc. - Construction of ESSOR test reactor. - Coordination of administrative, budget, contractual problems, etc.	A) Organic coolant studies 1) Chemistry - basic studies - technological studies - analytical methods - search for improved products - chemical engineering (purification, etc.) 2) Heat transfer - heat transfer coefficients - burn-out fluxes - physical properties - fouling studies 3) Physical Chemistry - compatibility - structural analysis of SAP - fission gas behavior in SAP or UC - fuel-cladding contact resistance - corrosion studies B) Metallurgy - shaping of UC and SAP - UC studies - fuel element studies - corrosion - mechanical and non-destructive tests - active tests - physical measurements C) Technology - pressure tube and its joints (SAP-stainless steel) - mechanical studies (mandrelling, vibrations) - effects on ORGEL vessel and connected tubes of pressure tube accident - thermal insulation - thermomechanical stability of components - general reactor engineering problems D) Reactor physics Physics & Mathematics : - neutronic studies - completion of ORGEL formula, ESSOR lattices, - control, dynamics, regulation, - construction and exploitation of ECO critical experiment (Expérience Critique ORGEL) EXPO experiment (Expérience Exponentielle ORGEL)
Works carried out at EURATOM headquarters and by contracts under supervision of Project Leader at Brussels.	Works carried out at the Ispra scientific departments and by contracts executed under their supervision

To carry out these works, the project has at its disposal the installations of the Ispra services and departments which, in most cases, are participating almost entirely in the ORGEL works (for example, the Technological and Metallurgical departments are participating for 90 % of the time).

Moreover, the project has or will have at its disposal after construction, a certain amount of specialized installations

- 3 loops for the in-pile irradiation of polyphenyls, two of which are inserted in the MELUSINE swimming-pool reactor at Grenoble (France) and one in ISPRA-I (Italy);
- 1 loop for the in-pile irradiation of substitutes to polyphenyl (MELUSINE, Grenoble);
- 1 loop for electron irradiation of organic products;
- 5 out-of-pile loops for heat exchange coefficient studies (2 in Ispra, 2 in Grenoble, 1 in The Hague, each one of them presenting, of course, different characteristics and objectives);
- 2 rigs for UC studies (Ispra and Petten);
- 1 out-of-pile loop for corrosion studies at Ispra;
- 1 organic-cooled thermal cycler (Ispra);
- 1 apparatus for in-pile testing of SAP creep (AVOGADRO, Salugg
- 1 rods and triplets irradiation loop (BR-2, Mol, Belgium);
- 1 ORGEL full-scale test channel (Ispra);
- 1 thermal insulator test rig (Ispra).

Particular mention should be made of :

- the ECO critical experiment (Expérience Critique ORGEL), Ispra
- the EXPO experiment (Expérience Exponentielle ORGEL), Ispra;

and, last but not least, the ESSOR reactor, now in the detailed design phase.

Some results obtained so far

As stated above, the main features of the ORGEL reactor system are basically :

- a low investment cost linked to the use of organic coolant;
- a simple fuel cycle without reprocessing linked to the use of heavy water.

It was clear that the knowledge existing in 1960 on organic coolants was much too limited to develop a real project. In particular, no data was available on organic analysis, on heavy or light high-boiler content, on mineral impurities, etc.; neither could one measure the physical properties of these liquids in reactor operating conditions.

Results available on corrosion and heat transfer (Colburn's relationship more or less modified) were unreliable. While utilizing the little information available, we launched a vast program aiming at the development of analytical methods and physical properties measurements. This program has produced a few basic results so far, particularly as regards methods to determine the water content in polyphenyls - which we are now able to identify down to a few ppm using a Karl Fisher method -; methods to determine high-polymer content in organic products, and methods for analysing, qualitatively or quantitatively, different polyphenyl components.

The determination of heavy products has been carried out through several methods, the most satisfactory being the vapor-phase chromatography with back-flushing. This method also makes it possible to analyse biphenyl and terphenyl isomers and, eventually, the quaterphenyls which are eluted in the direct sense and the heavy polyphenyls which are eluted in the reverse sense. The accuracy obtained is of the order of 3 %.

Analytical problems have been investigated by means of various techniques, among which particular mention must be made of the gaseous-phase chromatography which holds out promising prospects.

Analysis of mineral impurities is carried out through various methods : chemical method (chromatography or other), neutron activation, flame spectrometry, X-ray fluorescence or any other spectrographic method.

Flame photometry makes it possible to identify iron with an accuracy of 1 ppm, aluminum (1 ppm), nickel (3 ppm), manganese (0.5 ppm), copper (0.5 ppm). Higher accuracy can be obtained by the use of the calorimetric method : chrome (approx. 0.02 ppm), manganese (approx 0.4 ppm), nickel (approx. 0.04 ppm), copper (0.04), Mo (0.1), Fe (0.05). Spectrometry makes it possible to identify iron, nickel and copper down to one tenth of ppm. Iron, aluminum, nickel, manganese, copper, chrome, molybdenum, can be identified down to a fraction of ppm through any of these methods. Chlorine, which proved extremely detrimental to organic liquids, is equally being identified with very good accuracy through the calorimetric method.

As regards physical properties, special apparatus for measuring the specific heat, density, vapor pressure, thermal conductibility, have been developed and are in operation. They make it possible to determine, up to 450°C, the physical constants with a dispersion of $\pm$ 1 %, except for thermal conductibility where it reaches 2 %.

Such developments have made it possible to carry through detailed studies since it is now possible to analyse the ensuing results, particularly as regards corrosion where studies are being carried out on SAP and stainless or mild steel - electricall coupled or not - in organic liquid containing variable water content (from 0 to 500 ppm).

Although the experiments are still in progress, a few preliminary conclusions become apparent : the fact, for example, that the surface treatment of stainless steel present in the same liquid as SAP appears to be of great importance. We are now sure that SAP - and Aluminum provided certain precautions are taken - can be used as major circuit components in a reactor of this type, which, of course, influences the investment cost. As regards water content, it encourages corrosive deposits formation, but it is not yet possible to fix an inferior limit.

As regards technological studies of polyphenyls, we have already launched several in-pile irradiation campaigns including high polymer contents of 40 %, which have made it possible to carry out accurate measurements of physical constants on the product selected for the ORGEL project, namely the polyphenyl called OM-2, the composition of which is as follows : Orthoterphenyl 14 to 16 %, M terphenyl 79 to 81 %, P terphenyl 3 to 5 %, Biphenyl 1 %.

Its current price is $ 0.6/kg but it could be reduced to $ 0.5 to $ 0.4/kg in the case of mass production.

The mixture was selected because of its relatively low melting-point (65 to 80°C), which decreases at room temperature as the high-boilers content reaches 30 %. Moreover, its radiolytic and pyrolytic behavior is, according to works carried out under ORGEL contracts, quite near that of paraterphenyl and the price is much cheaper than a richer orthoterphenyl mixture.

All ORGEL works without exception - carried out under contract or at EURATOM - are being done with this product, the composition of which is continuously being investigated so as to remain constant.

Research is under way to investigate the problem of substitutes to terphenyls. A petroleum by-product of α and β methylnaphtalene has been developed. Radiolysis and pyrolysis are satisfactory when fluid is maintained at not too high a temperature; however, the drawback is its high vapor pressure (similar to that of biphenyl). It is therefore not suitable for an ORGEL reactor type, but it can be used as an intermediate thermal fluid in a test reactor such as ESSOR, inasmuch as it presents one advantage as compared to regular organic liquids : the molecule does not contain any oxygen.

Alkylphenanthrenes are also being investigated : Their radiolytic resistance is comparable to that of polyphenyls; however, the pyrolytic resistance is lower. The factor by which they should be cheaper than the polyphenyls to become competitive in an ORGEL reactor type can now be fixed to 10. Of course, the situation would be entirely different - and more favorable - in a wholly organic reactor.

As regards the neutron balance, buckling measurements have been carried out in the AQUILON reactor at Saclay (France) on organic-cooled oxide bundle lattices. The experimental values proved to be superior to the calculated values, which has made it possible, not only to correct our formula but to "recuperate" a few reactivity points, which are always useful in a natural uranium reactor.

Efforts are being concentrated on technology and metallurg The basic structural material is now SAP (Sintered Aluminum Powder). This material, quite uncertain a couple of years ago, has been investigated to such a point that its use in a reactor type can now be envisaged without apprehension.

It is, of course, necessary to distinguish the cladding material from that of the pressure tube. The former shows a relatively low aluminum content (4 to 7 %); it permits the fabrication, by extrusion, of finned cladding tubes showing very good dimensional characteristics on a length reaching approximately 2 meters. Several welding processes are being investigate ultrasonic method, hot pressure, arc welding, brazing, electron bombardment, etc, but it is still too early to raise a definite opinion on these methods. However, at least two of them (arc welding and electron bombardment) have resulted in strong and leak-tight welds.

As regards the use of SAP as pressure tube cladding, research is less advanced. However, explosion and creep tests are in progress, under pressure and high temperature; the figures found up to now are rather satisfactory but it remains a difficult problem of dispersion in the results.

We are considering carbide, oxide and metal as possible fuels. As regards carbide, we are investigating several preparation methods : sintering, reaction under load, arc-melting, vibration densification. It is impossible at the time being to evaluate the economical prospects of these methods.

Low-alloyed metal (1 to 2 % Mo), because of its low price and a reasonable behavior under irradiation, appears to be a valuable fuel. Moreover, from a neutron viewpoint, it is satisfactory. The problem is the development of a diffusion barrier between U and cladding.

As regards nickel, it was found out that 70 $/^{u}$ of nickel were necessary to protect the rod during one year at 450°C which, from a neutron viewpoint, is prohibitive.

Chrome and niobium are being investigated.

A well fitted fuel is that permitting to reconcile technological and neutron burn-ups; it might be intèresting to envisage a slight enrichment if carbide is used in order to take fullest advantage of its properties and to exceed the 8000 MWD/T which it is hoped may be reached with natural uranium.

As regards oxide, it suggests greater division than carbide and, from a neutron viewpoint, it is rather inferior. It is however being considered as a possible fuel, but no research has been undertaken for ORGEL in view of the fact that numerous studies are being carried out in this field throughout the world.

In addition to the out-of-pile and in-pile installations described above, particular mention should be made of two important achievements :

1. The ECO critical experiment (Expérience Critique Orgel)

ECO is a low-power critical assembly, moderated with heav water, a large volume of which (25 tons) is available. This will allow the accurate measurement of small buckling factors (1 to 1.5 m^{-2}) and also on unreflected lattices. The replacemen method will be used, with a reference lattice consisting of clusters of 19 uranium metal rods surrounded by organic liquid (eutectic ortho-meta-terphenyl, the fusion and boiling temperatures of which range from 30 to 400°C respectively) in an alumin tube. The reference lattice can be modified by putting the rods in clusters of 12 or 22.

One of the original features of ECO is that it will be possible to heat the substitute lattice (maximum 24 rods), which will be made up of independent cells suspended in place of the normal elements of the reference lattice. A cell is made of the cluster, its pressure tube, a circulation pump for the organic, an electric heating device (4 KW maximum) and a temperature regulation device. Pitch is altered by a device which may possi be made to oscillate around a fixed value if the hydraulic mock-studies now in progress provide positive results. If so, it wil be possible to measure not only buckling at a given pitch but al the tangent at that point, thus considerably increasing accuracy

The ECO reactor will have a mechanism for oscillating the central element. With this device it will be possible both to observe more accurately the effect of replacing a rod and to study long-term changes by replacing part of the centre rod, eit by a section of synthetic rod simulating the state of the fuel after irradiation or by a rod section irradiated in the ECO reac

It is also possible to introduce a detector to observe th reactor in pulsed operating conditions by means of an electrostatic accelerator. Finally, a neutron pulse can be removed either from the vertical centre channel, either by immersing in the heavy water an empty tube coming out opposite a horizontal channel located in the protection. The pulse may be analysed by time of flight. As detection techniques improve, a I KW power should be satisfactory to secure good statistical accuracy on spectrum measurement.

The ECO reactor also includes substantial mechanical improvements as compared with other reactors of this type; in particular, the heavy water circuits which make it possible to accurately determine the heavy water level in the vessel.

ECO is now in the constructional phase under contract with the Dutch concern NERATOOM. It should be operational in July 1963.

2. ESSOR (ESSai ORgel), a specific test reactor for the ORGEL program.

Its main object is to try out and develop power reactor sub-assemblies, one of the most important of which is the channel, i.e. the assembly consisting of the fuel, the coolant liquid, the thermal insulator and the pressure tube with its junction to the outer pipes.

For this purpose, the reactor is composed of two zones : one central zone called the "ORGEL zone" consisting of 12 "positions" into which the complete ORGEL channels of various designs can be fitted, the other is a peripheral zone called the "feeding zone" and consists of BR-2-type highly-enriched uranium elements cooled by heavy water circulation.

This arrangement makes it possible, at a fairly low total power (30 MWth), to try out and develop ORGEL-type channels equipped with natural uranium fuel in conditions approaching those of a power reactor.

The central zone is provided with a great degree of flexibility, since it can be employed for trying out different channel types (variable diameters, uniform constitution or various materials interconnected by means of joints, expansion compensation, various thermal insulators, etc. and, in some cases, fuel extraction during operation).

Four of the 12 ORGEL channels are each hooked up to an individual cooling circuit, and the eight others to a common circuit. The four circuits called "single loops" make it possible to try out either various fuels and to observe burst cladding phenomena on one of them, or to study complete channels of various designs, coolants of varying compositions, purifications, degassing pressurization devices, etc.

The eight channels connected to a common circuit make it possible to carry through, over a longer period and in parallel, the development of sub-assemblies selected in the "single loops".

The operation of the ESSOR reactor has been basically designed to meet with the experimenters' requirements. The fuel element handling systems and sub-assemblies constituting an ORGEL channel have been arranged so as to permit cleaning, examination, reinsertion of fuel elements in the core; removal, examination, dismantling in various cells of the channel components; as well as insertion into container, de-activation, dismantling, detailed study of fuel element clusters. The instrumentation and reactor control have likewise been separated; control is being taken care of by a single operator while the experimentator has at his disposal to crosscheck the experiments a system for the automatic processing of measurements and an auxiliary control room for loops, allowing him, under the reactor operator's supervision, to carry out various measurements on the five simultaneously tested loops.

The ESSOR reactor, due to the flexible arrangement of the central zone and ancillary circuits, and by virtue of the numerous possibilities open to the experimenter during operation as well as the relative freedom afforded by the presence of a feeding zone, should make it possible to try out sub-assemblies of various designs, and to observe and evaluate experimental progress. It appears to be one of the means best adapted to the study of various solutions leading to the final reactor design.

The detailed project is in a very advanced stage, and the exact site has been selected. The ground should be broken in October, 1962, and we estimate that the construction will take 3 years.

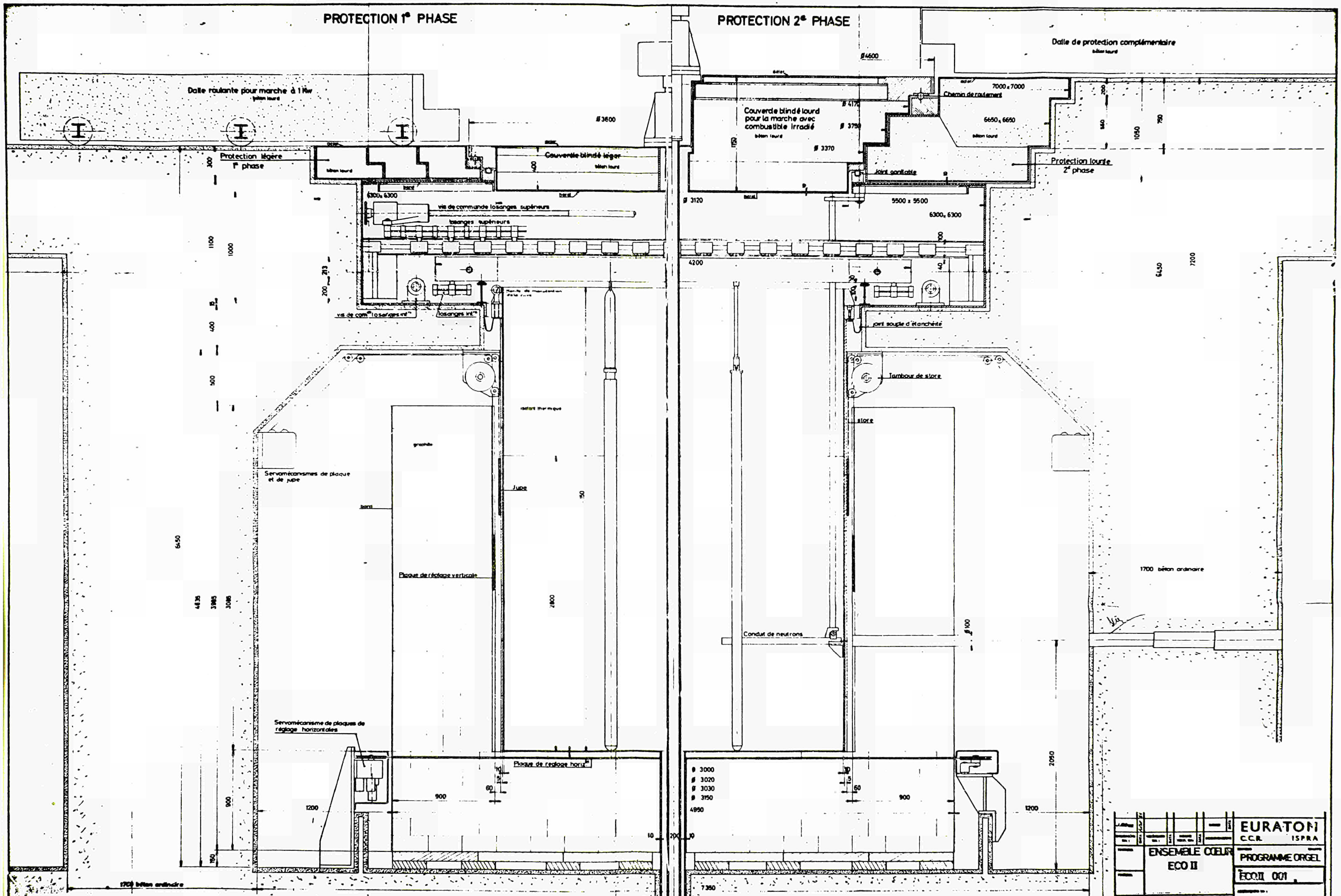
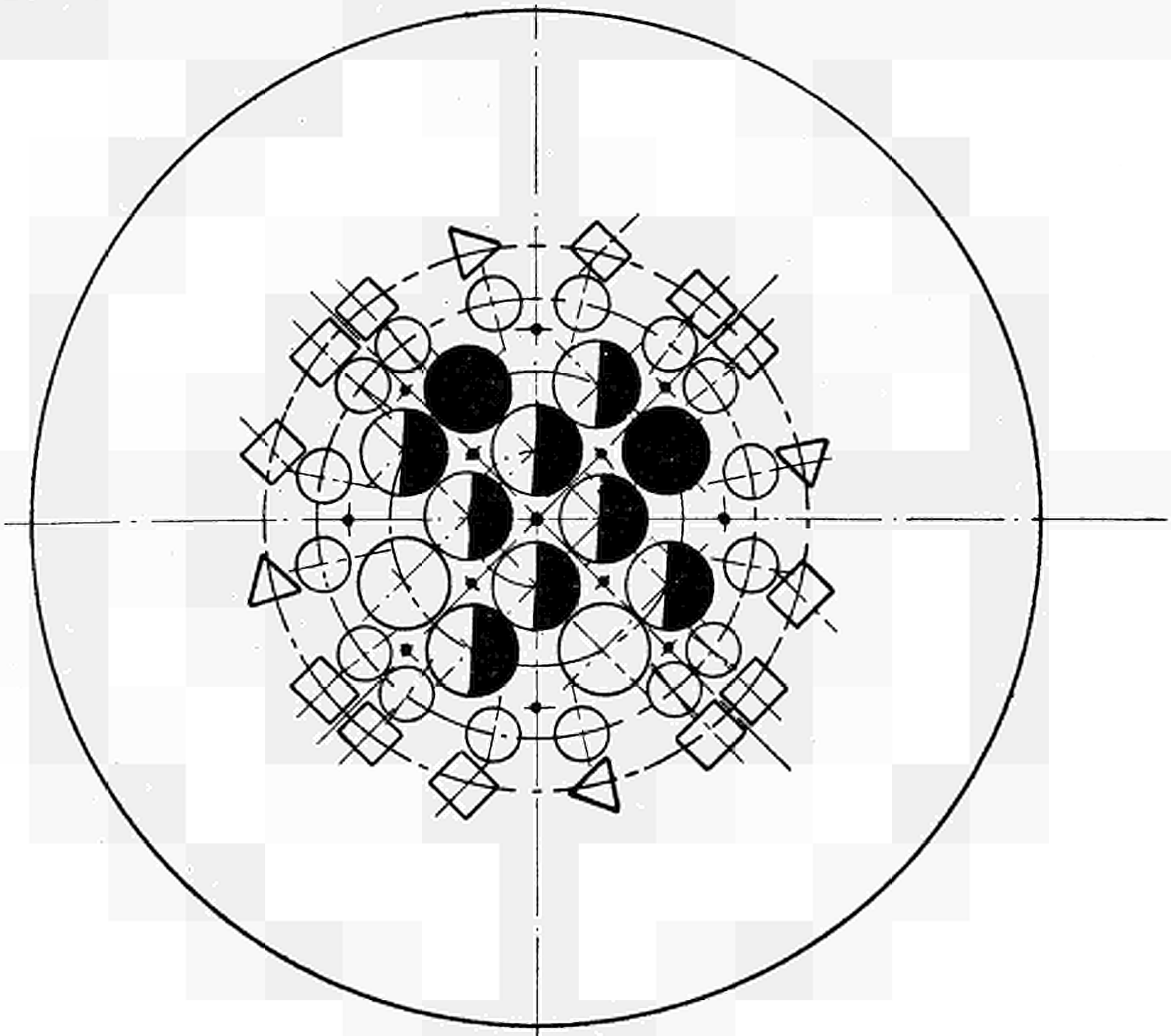


Fig. 1 - ECO core : General view.



- ● 2 BS type D
- ○ 2 BS type E
- ◑ 8 BM type E
- ○ 16 Nourrices
- □ 12 Barres de contrôle
- ▽ 4 Barres de sécurité
- • 13 Mesures de flux

FIG 2 ECH : 1/20

REACTOR SCHEMATICAL
CROSS-SECTION

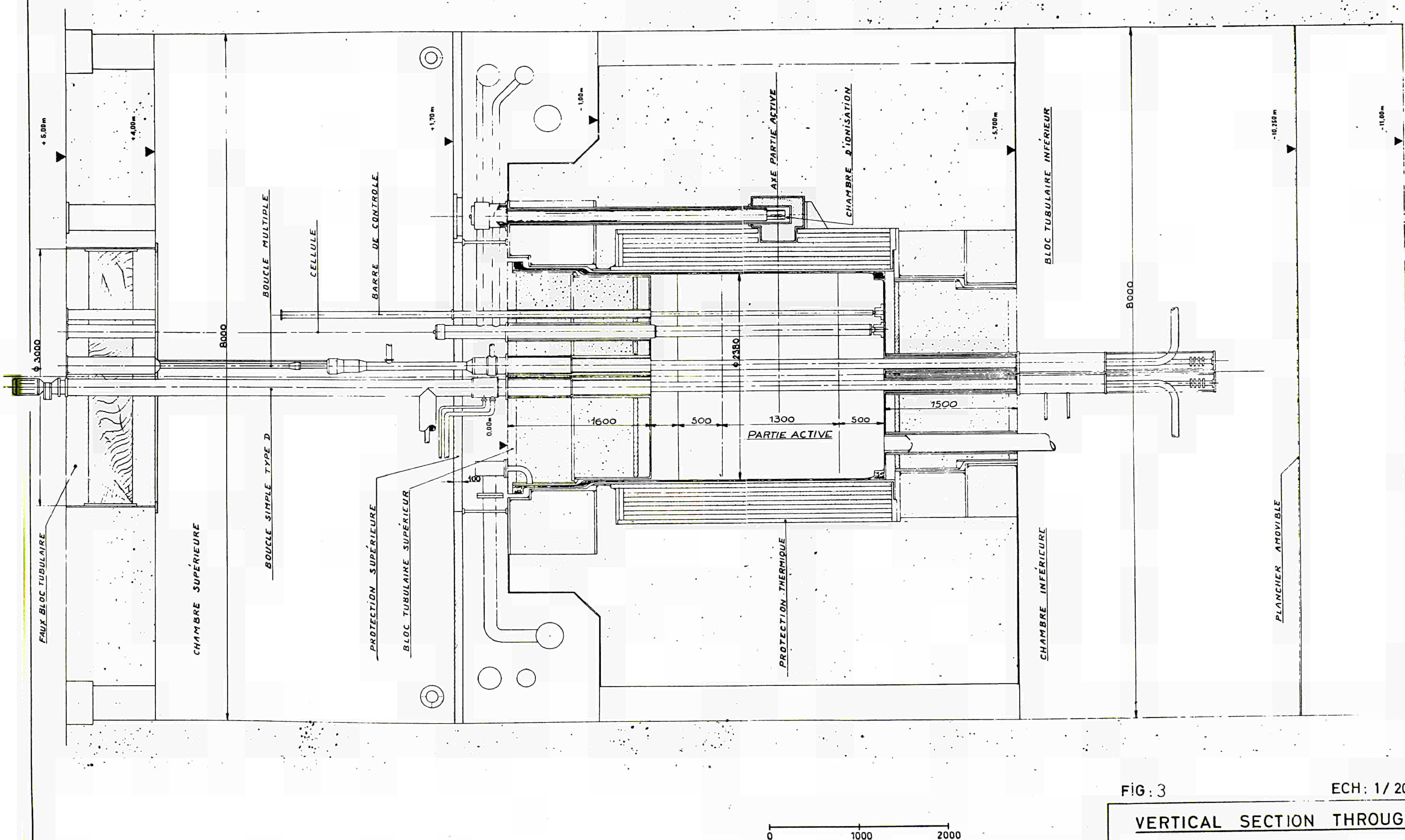


FIG: 3

ECH: 1/20

VERTICAL SECTION THROUGH ESSOR REACTOR

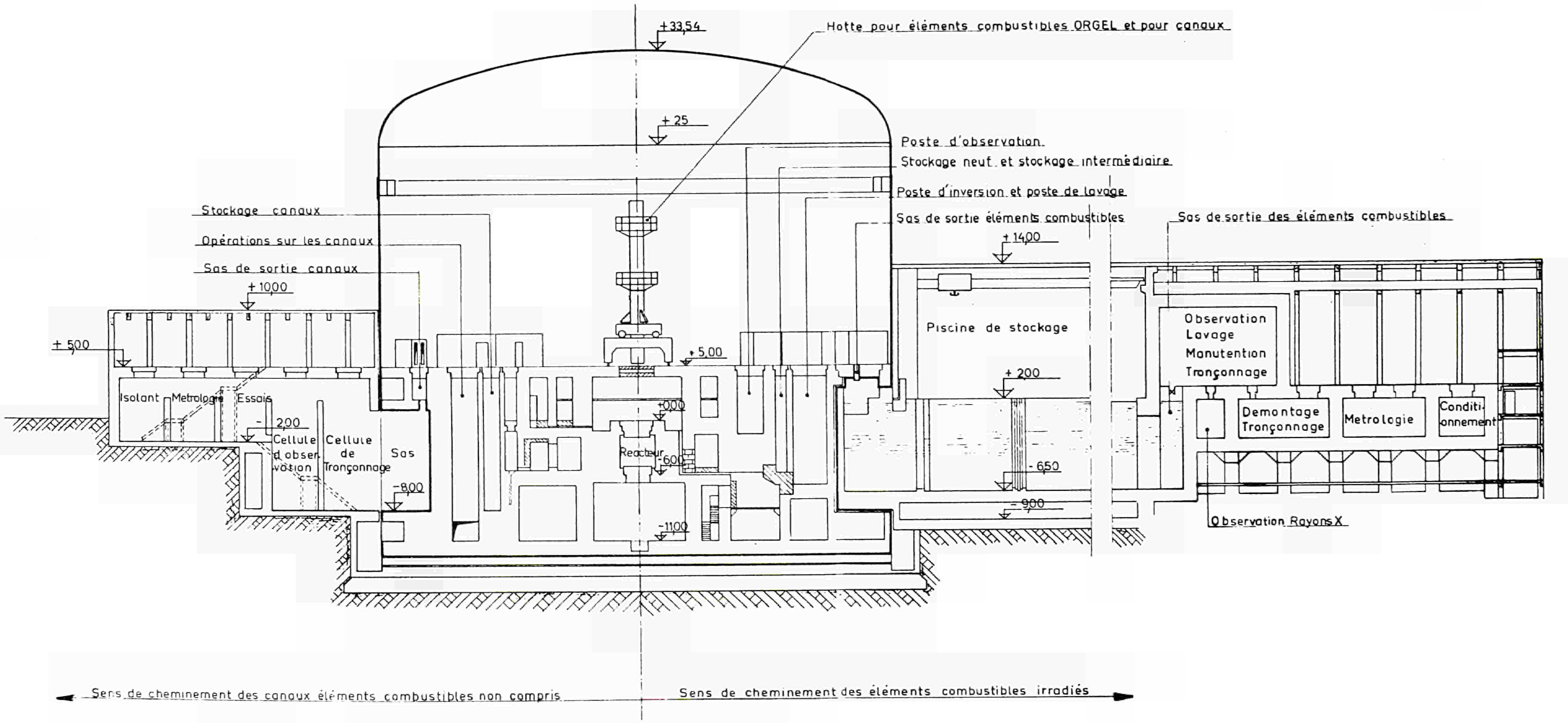


FIG : 4

ECH : 1 / 200

SCHEMATIC OF FUEL AND CHANNEL HANDLING