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STATUS AND PROGRAMME OF DEVELOPMENT OF THE FAST BREEDER REACTOR SYSTEM IN THE FEDERAL REPUBLIC OF GERMANY

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I. The reasons behind the fast breeder development

The fast breeder reactor development has a special characteristic which at the same time constitutes its strength and also its weak point:

- It is being implemented simultaneously in a number of countries along the lines of one identical technical basic concept. This means that a world-wide technological basis has been provided together with the possibility of direct cooperation both with regard to development and to introduction on the market.

- This global development (Fig.1) might mislead an individual country into not giving proper consideration beforehand to the issue of whether fast breeder reactors are a necessity for itself under the individual socio-economic aspect (optimum size of power stations, existing infrastructure, etc.). Each country will have to study its own specific local requirements and resources with a view to an optimal solution of the long-term energy problems.

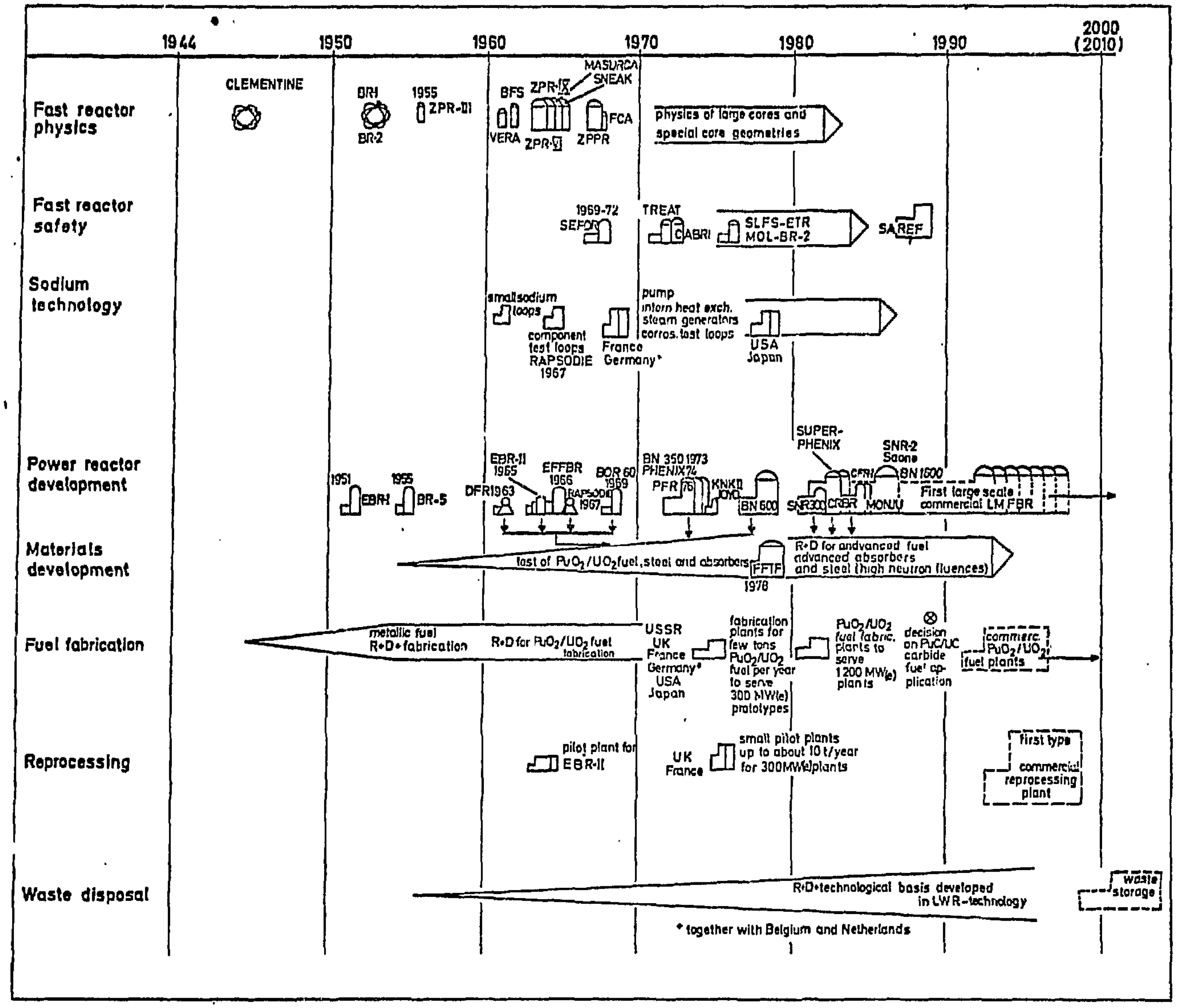


Figure 1: Development Strategy for the Fast Breeder Reactor System

In the following, an attempt is made to describe the present state of the art in the Federal Republic of Germany. In this connection the reasons proving the necessity of fast breeders in this country shall first be presented.

Studies concerning energy consumption and therefore also involving power growth rates covering two decades are, of course, hampered by considerable uncertainties, because the political implications or changes in habits during such periods of time can only be roughly assumed and not forecasted with a reasonable degree of reliability. Statistical experience to date shows that a functional connection exists between the average annual growth rate in net electric power consumption and the corresponding growth rates of the real gross national product (GNP). Retrospective studies provide the following data for

1973 - 1985: 2.8% up to 3.4% annual growth rate of the gross domestic product

with 4.9% up to 6.2% annual growth rate of net power consumption.

Model studies which combine these quantities arrive at the following forecasts (1) for

1985 - 2000: 2.2% up to 2.8% annual growth rate of GNP

with 4.6% up to 4.8% annual growth rate of net power consumption.

These growth rates and the specific raw energy situation in the Federal Republic of Germany require a relatively high number of nuclear power stations. At present nuclear power stations with an installed capacity of 6,350 MWe account for approximately 8% of the overall generation of power. Additional nuclear power stations with a total capacity of 14,000 MWe are either under construction or in the advanced planning stage. At the same time it must, of course, be admitted that the planned schedule has been delayed as a result of opposition to the use of nuclear energy. Up to 1985, the key dates and guide-lines for the second revision of the energy programme of the Federal Republic of Germany provide for the desired total nuclear energy capacity of up to 30,000 MWe (2), which corresponds to 26% of the power station capacity installed at that time. During the above-mentioned period, almost all commercial nuclear power stations operating will be of the Light Water Reactor Type (LWR).

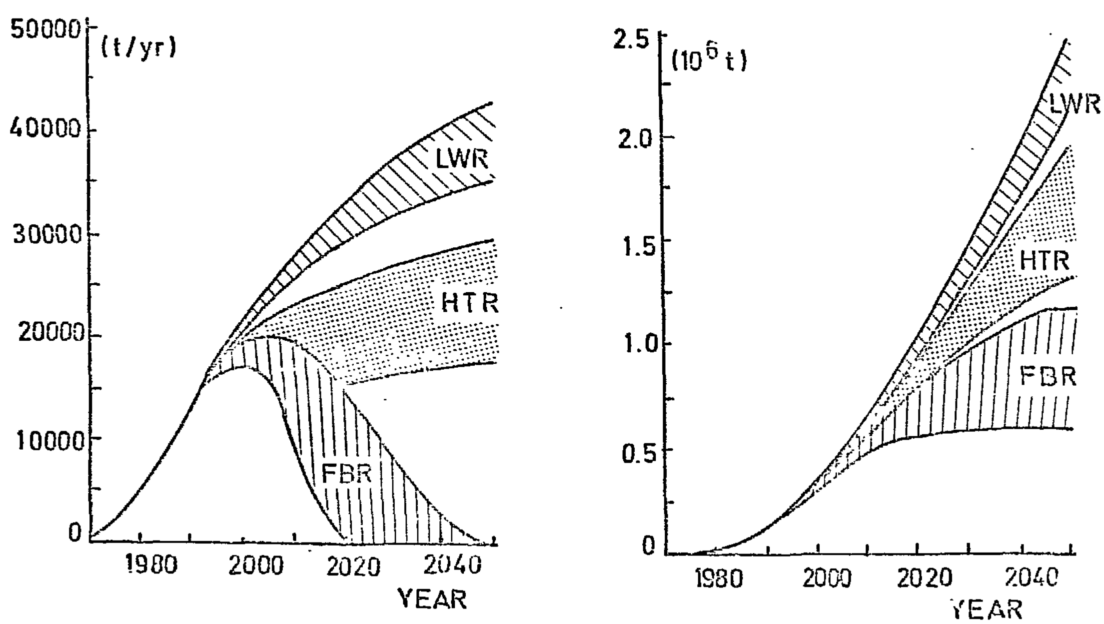
Given the volume of the world's uranium-resources, however, nuclear energy will not be able to play a long term role in the world's energy supply as long its utilisation is solely based on light water reactors. Seen from this angle, the development of fast breeder reactors constitutes a necessary complement to light water reactors - on the one hand in order to be able to become more independent from the uranium supplier countries - and on the other hand necessary in order to be able to make use of the plutonium accumulating in light water reactors.

The estimated global uranium reserves are rather uncertain. For a specific country, it is not the estimated world uranium deposits which play a decisive role as a basis for planning, but rather the amount of uranium to which a specific country has guaranteed access. In addition to political obstacles it must also be considered that finally limits are set for the supply of uranium-depending on the available mining and processing capacities, and that considerable time is required for the opening up of uranium deposits in unexplored geographical regions. Recent developments in some of the uranium supplier countries will enforce a tendency towards more nuclear fuel autonomy in many countries.

For the DEBENELUX group of countries, the cumulative natural uranium requirements from the year 1970 up to 2020 are estimated to be 1 million tons in all, rising during the period up to the year 2050 to approximately 2 million tons. In contrast, world uranium reserves with extraction costs amounting to up tc \$ 30 per lb U_3O_8 are estimated to amount to merely some 3.5 million tons. Considered realistically, such high requirements can hardly be expected to be met if account is taken of the fact that the population of this group of countries in the year 2000 will amount to merely about 1% of the world population. Even if the estimates of the world uranium resources are to low a factor of ten, the picture does not change in principle for the Federal Republic of Germany.

As far as conditions in the Federal Republic of Germany are concerned, this means that a forsighted and systematic policy guaranteeing the fuel supply for West Germany's nuclear electricity generation cannot defer the possibility of the utilisation of the fast breeder reactor which has now been developed in the Federal Republic of Germany since 1960.

Detailed studies (3) show that, with the gradual additional construction of breeder reactors in an established light water reactor scene, the annual requirements of uranium ore might at approximately the middle of the coming century drop to almost sero. It will then be possible to meet the breeder reactor's fuel requirements by the depleted uranium accumulating in the light water reactor power stations. It is expected that fast breeder reactor power stations in the Federal Republic of Germany and in the BENELUX countries will be commercially available towards the end of the 1990ies. A decision on the time and scale of breeder reactors, however, has not been reached. I will have to rely on the experience gained with the SNR-300 project and in addition depend on the overall development of the nuclear energy policy in the Federal Republic of Germany.



a) Annual demand Fig. 2 b) Cumulative demand

of natural uranium for the production of electricity and process heat in the DeBeNeLux countries. Estimated ranges for

- Light water Reactors (LWR) only
- LWR + High Temperature Gas-Cooled Reactors (HTR)
- LWR + Fast Breeder Reactors (FBR) with oxide or carbide fuel.

II. Development programme in the Federal Republic of Germany

Following a lengthy selection procedure in the Federal Republic of Germany, the decision has now been taken to apply the sodium cooling system used throughout the world. A 20 MWe experimental power station was built at the Karlsruhe Nuclear Research Centre, primarily for the purpose of studying all about sodium technology. This power station is known as the KNK. The Kompakte Natriumgekühlte Kernreaktoranlage was developed originally under the German Atomic Energy Programme as an experimental sodium-cooled thermal power reactor. It is similar to JOYO, DFR, EBR II, SEFOR, RAPSODIE and BOR 60, which are cooled by liquid metal and have power levels between 40 and 100 Mwth; the KNK differs from most of them inasmuch as it is a nuclear power station.

The construction of KNK was started in 1966; the reactor became critical in 1970 and rose to full power operation in 1973. The plant has been operated on the power grid almost continuously at 100% power level with a thermal UO_2-core until late 1974.

KNK was built under a general contract which includes many features of a genuine utility order for a nuclear power station; there are penalties with respect to guarantees and time of delivery, completeness clause, state-of-the-art-clause etc. The licensing procedure was similar to that adopted for commercial light water reactors. Because of the almost urban siting - the city of Karlsruhe is only 10 km away - the application of stringent safety criteria was unavoidable. It was one of the objectives of KNK to serve as a model for the licensing of sodium-cooled reactors in Germany. SNR, the 300 MW demonstration plant at Kalkar, is based to a great extent on the experience gained with KNK.

At present a conversion of KNK II is under way. The thermal KNK I core is being replaced by a fast UO_2-PuO_2-core. In this connection the licensing authorities called among other things for a new type of fuel element storage, additional safeguards against earthquake effects, a modified fuel handling machine, an additional emergency diesel building and an emergency core cooling system.

KNK II will mainly be used for experimental purposes. KNK II will precede the following SNR by a period of roughly 4 years. By then, much of the experience gained with commissioning and operating KNK II may be transferred to SNR. The critical experiment for KNK II is expected in fall 1977; full power operation should begin in 1978.

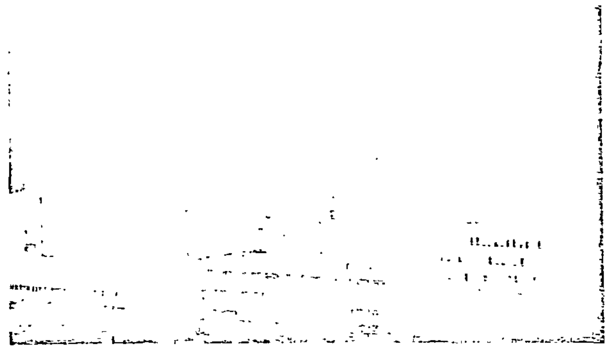


Fig. 3: Overall view of KNK

It was recognized early in the Federal Republic of Germany that major development projects would have to be carried out on the basis of international cooperation. In 1972, the Federal Republic of Germany, Belgium and the Netherlands agreed to construct jointly a 300 MWe prototype power station equipped with a sodium-cooled fast breeder reactor (SNR 300).

The organization of the international project structure is shown in Fig. 4. The turnkey contract for SNR 300 has been let by SBK to INB.

The parent companies of INB's shareholders represent a powerful industrial grouping of which KRAFTWERK UNION, as the 100% shareholder of Interatom and certainly one of the most experienced European power plant designer, is the backbone. Belgonucléaire is half owned by the Belgian Government, most of the other half of industrial shares belonging to Union Minière. 45% of the Neratoom shares belong to the Dutch Rijn-Schelde Verolme (RSV) and the rest to the Verenigde Machinenfabrieken (VMF) groups in which most of the Dutch manufacturing capabilities for heavy euqipment are concentrated

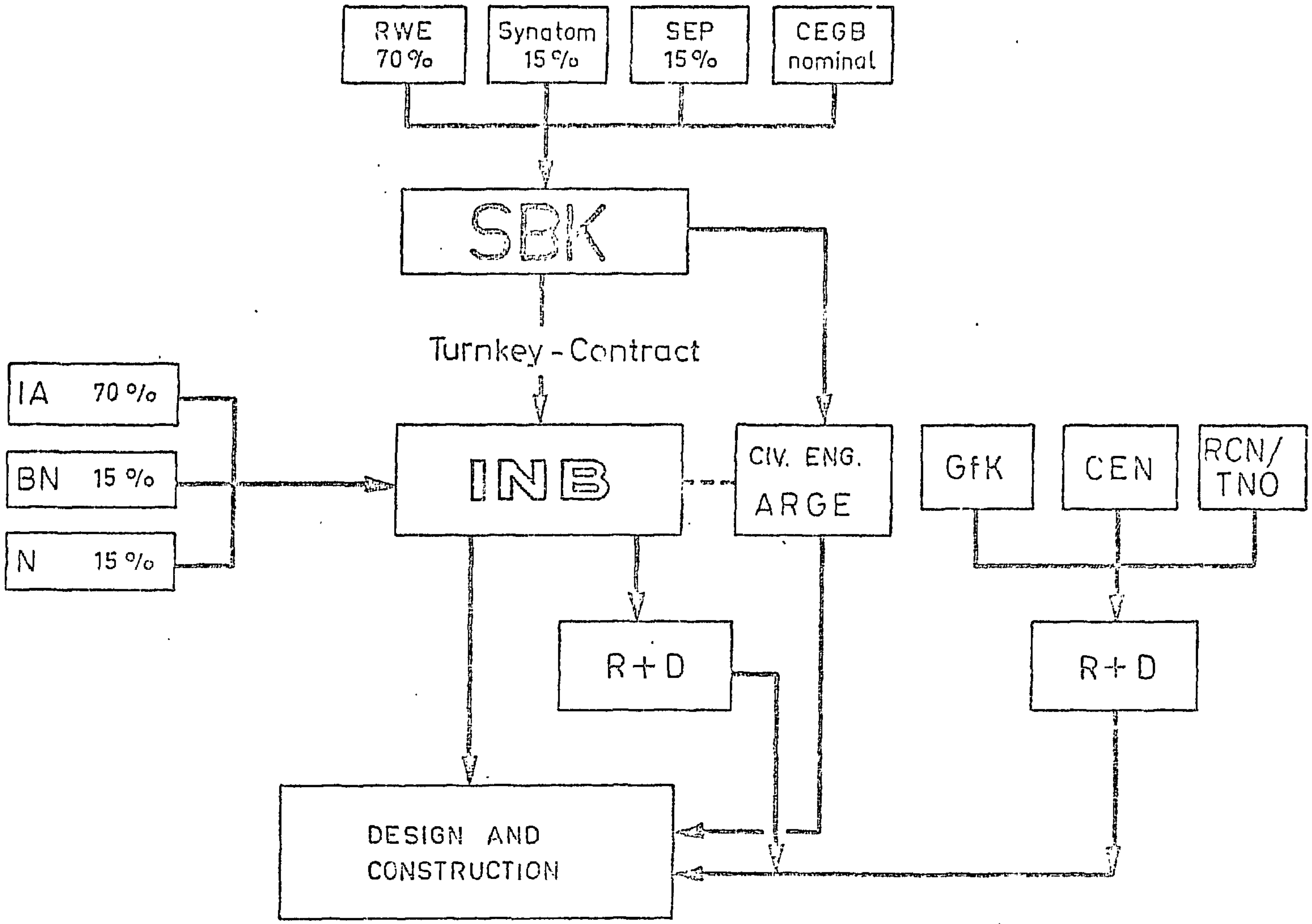


FIG. 4 . ORGANISATION SNR 300

and which together employ about 50,000 people. INB shareholders and their partners provide the manufacturing capabilities for such special sodium breeder components which, due to their intense interconnection with the system development, cannot be provided from unspecialized industry. So the Dutch group manufactures steam generators, IHXs, and main coolant pumps for SNR 300. Interatom provides control rods and their drives and special sodium instrumentation. Both Belgonucléaire and the German ALKEM, a KRAFTWERK UNION subsidiary, provide the fuel and blanket elements. The turbo generators, the general plant control and instrumentation are provided by KRAFTWERK UNION. Different from the approach in some other countries, however, INB sub-contracts most of the components and subsystems of the nuclear steam supply system (NSSS) to independent manufacturers.

In Fig. 5 the main data of the 327 MWe loop design prototype SNR 300 are summarized.

Thermal power	762 MW
Electrical power	327 MW
No. heat transfer loops	3
Sodium inlet temperature	377 °C
Sodium outlet temperature	546 °C
Fuel elements	205
Pu inventory	~1200 kg Pu-239 equ
Start construction	1973
Full power operation	1982
Owner/Operator	SBK
Design and turnkey construction	INB

Fig. 5: KKW Kalkar, main data

The time schedule for the SNR 300 construction is given in Fig. 6.

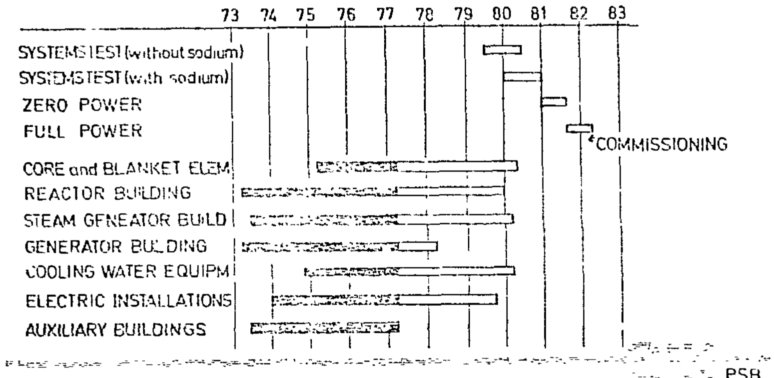


Fig. 6: SNR-300 TIME SCHEDULE

A characteristic feature of our policy is reflected by the fact that prototype fast reactors - in contrast to other countries - are subjected to regular licensing procedures because the establishment of a competent licensing authority must be introduced as early as possible. Admittedly, this brings about a temporary slowdown in the rate of development. From our point of view, however, it constitutes a major prerequisite for the later commercialization of a new reactor line.

The applicant for the construction and operation licence in the case of the SNR 300 is SBK, as the owner/operator of the plant. The licenses are granted by the responsible Ministries of the Land in which the reactor site is located. Several independent agencies and expert groups assist in decisions, and the Federal Ministry of the Interior has the right to supervise the Land prior to granting a licence.

In contrast to the procedures in most other countries, a construction licence in Germany does not at all allow construction of the whole plant, but only accepts the feasibility of the safety concept of the plant. During construction there is a continuous process of further licensing steps.

Until loading a number of licences have to be obtained for the construction of both concrete structures and components. Such licences can only be granted on the basis of detailed information supplied to the authorities and a through review by independent organizations; mainly by experts of the TÜV organizations. Many requests for additional information are raised during the review, and all modifications to the original information must be approved again.

The present realization of the project is determined by the partial licence for the biological shield with problems to be solved regarding

- the release of water vapour from the concrete structures of the reactor forming at temperatures up to 200 °C during the post-Bethe-Tait phase
- the high temperature properties and resistance to radiation of the thermal insulation of concrete structures.

In 1977/78 another two partial licences will have to be applied for, which will concern

- the reactor vessel with the vessel support girders and the rotating reactor top shield,
- the primary and secondary heat transfer systems,
- the bottom cooling system (core catcher)
- the shutdown systems.

It will depend on the course of discussions on these partial licences whether or not further delays will occur.

Delays during the construction of SNR 300 have also resulted in cost increase, directly and indirectly.

Compared with the estimated total costs of DM 1,535 million in 1972, which marked the beginning of the SNR 300 project, we now expect the construction costs to reach a total of DM 2,276 million, which means extra costs of DM 741 million. These additional costs have meanwhile been approved by the participating governments of the Federal Republic of Germany, Belgium and the Netherlands, so that total funding of the SNR 300 project will be guaranteed.

In addition to the above-mentioned projects and plans, supporting R&D programmes are being carried out at the Karlsruhe Nuclear Research Centre. These studies focus mainly on the physics and safety of fast breeders, as well as on improving fuel elements. The activities also include irradiation tests and studies concerned with high-power fuel on the basis of uranium-plutonium carbide, which could bring about a marked improvement in the efficiency of large fast breeder reactor power stations. In addition a programme for the development of canning materials and structural materials is being performed. Such development activities are also coordinated with the relevant industry and corresponding agencies in the Benelux countries. It is now increasingly paying off that we are able to carry out our domestic development on the basis of the experience acquired with a breeder concept adopted throughout the world, namely by participating in a steadily growing exchange of experience at international level.

In the Federal Republic of Germany, the fast breeder reactor development is oriented to the requirements of a free market economy, i.e. the government, power supply companies, reactor manufacturers and nuclear research centres regard themselves as partners in a community concerned with development. As the development attains greater maturity, the financial burdens are transferred increasingly from the shoulders of the government to private enterprises. Whereas basic research is still financed solely from public funds, the electricity supply companies are already deeply committed in the sector of prototype reactors. With regard to the demonstration phase, the goverment will for the most part only bear a share of the non-commercial costs and undertake to cover specific risks.

III. Advanced programmes in the field of international cooperation

It is a fact that the introduction of fast breeders is determined to a decisive extent by both the available supply and price of uranium. The time of introduction can therefore not be established precisely. Hence that the construction of fast breeder nuclear power stations on a full commercial basis within the international framework can hardly be expected in the near future, particularly when considering that the fuel costs advantage of this system is used to the full only after the fuel cycle has been closed. As a result, all those countries interested in this system are compelled to cooperate in order to distribute the development expenses among the partners and to assist its introduction into the market and retain the engineering capacity over a long period.

The electricity supply companies in Europe have realized this fact early and an extensive European integrated utility corporation facilitates cooperation along such lines. The utilities involved in NERSA (EdF, ENEL, SBK) for the French Super-Phénix project, are also partners in Europäische Schnellbrüter-Kernkraftwerksgesellschaft (ESK) for the German SNR 2 project.

Both NERSA and ESK were established in 1974, with a majority shareholding of EdF in NERSA and SBK in ESK, respectively.

A first conceptual design study on a 2,000 MWe LMFBR demonstration plant funded by ESK had been completed by the German-Belgian-Dutch company INB early in 1976.

Whereas this preliminary project study used a reference plant of 2,000 MWe, the power level of the NSSS has recently been fixed at 1,300 MWe with a stretch-out capability to 1,500 MWe.

Planning activities are accompanied by a government-financed R&D programme, which is intended to support - for the moment by way of key experiments - the establishment of a general concept for licensable facilities. Owing to this being linked with the successful commissioning of the SNR 300 prototype power station, a building contract is not expected before 1983/84. Such a building contract is preferably to be awarded by the utility companies.

In parallel, further negotiations of the utilities with regard to the construction of the Super-Phénix finally led to a 16% share of the DEBENE group SBK, in accordance with an agreement concluded late 1973 between the utilities RWE-ENEL-EdF. The participation of SBK in the Super-Phénix project at the same time commits EdF and ENEL to participate in a German SNR 2 project.

Up to now it has not been possible to establish broad-based cooperation on the manufacturers' side. The individual stages of development, the critical facilities, the experimental reactors in the 20 to 50 MWe class, the prototype reactors of 300 MWe size and the demonstration reactors in the 1,000 MWe range are being fully repeated in the different countries; - a situation which up to now has not resulted for any country in the commercial introduction of this system. With regard to the problems of the introduction of the fast breeder system, the problems still confronting us today can be successfully dealt with only by way of international cooperation, carried out on a scale which has hitherto not been the rule.

Since late 1975, closer cooperation of the German-Belgian-Netherlands fast breeder manufacturers group with France has, therefore, been under negotiation.

As a follow-up to a joint declaration by the German and French research ministers on 13 February 1976 concerning closer cooperation in the field of advanced reactor development, memoranda of understanding were signed on 18 May 1976 between

- Interatom and CEA	concerning cooperation in the field of LMFBR
- GfK, Interatom and CEA	concerning cooperation in the field of R&D work for LMFBR
- INB and Novatome	concerning industrial and commercial cooperation on LMFBR

accompanied by guidelines of the governments for cooperation in the field of advanced reactor development.

Such cooperation, together with the permanent links between the utilities, would lead to an extended industrial structure as shown in Fig. 7.

The main aims of the cooperation envisaged are

- to increase the feasibility, licensability and competitiveness of LMFBR's
- to minimize the commercial risks and the costs incurred by the introduction on the market of the LMFBR
- to improve the commercialization of LMFBR by the industries concerned, both in Germany and France, and by means of exports to third countries
- to mutually benefit from the knowledge of the partners involved on a commercial basis by granting licences
- to rationalize future R&D efforts.

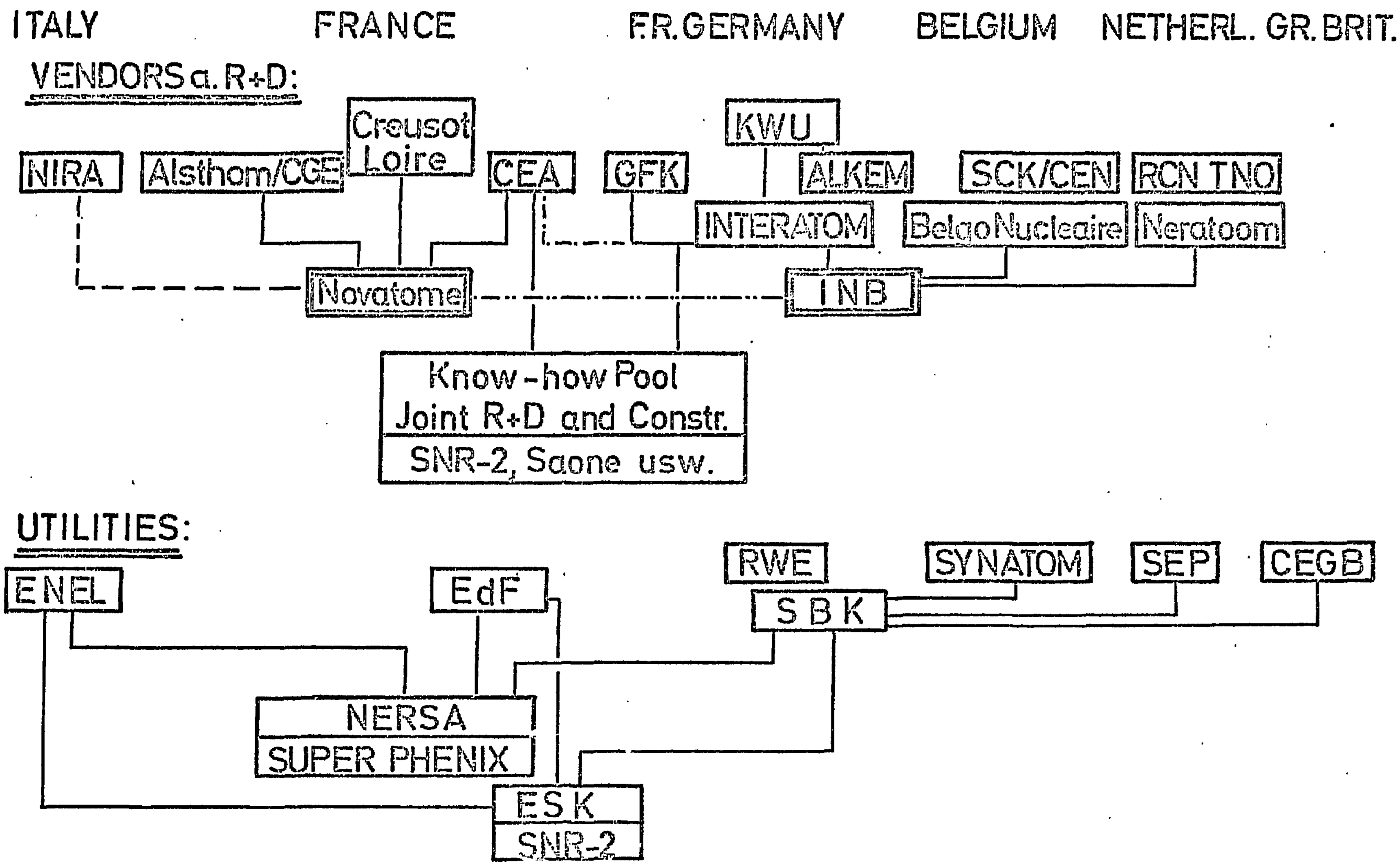


FIG.7: BREEDER COOPERATION in the EUROPEAN COMMUNITY

A deadline for the final signature of the respective contracts has now been set for end of May 1977.

The picture drawn in this paper of the German fast breeder development would be incomplete if the funds appropriated for this purpose were not mentioned. From 1960 up to the end of 1976, approximately DM 1.3 thousand million have been spent on basic research and on the construction of test and experimental facilities.

Until it will be taken over in 1982, construction of the SNR 300 prototype reactor will require approximately DM 2.8 thousand million, of which about 30% will be borne by the Belgian and Netherlands partners.

Above and beyond this, the Federal Government is making available a sum of up to DM 105 million for risk-covering in connection with the operation of the SNR 300 prototype reactor.

For the time being, the amount of some DM 250 million has been earmarked for advanced planning and development activities in connection with the SNR 2 demonstration fast breeder reactor for the period up to 1981.

At the Karlsruhe Nuclear Research Centre, funds amounting to approximately DM 90 million are included in the budget each year for research and development work on the fast breeder.

We are convinced that by pursuing the course taken we have laid the foundation stone for an energy supply guaranteed over a long period to come. During the next few years it will be a matter to make optimal use of all the available sources of primary energy in order to reduce our dependence on imported crude oil.

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