International
Nuclear
Fuel
Cycle
Evaluation

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INFCE/DEP./WG.3/7

TOPICAL PAPERS ON HEAVY WATER, FUEL FABRICATION AND REACTORS

INFCE WORKING GROUP 3

TOPICAL PAPERS ON HEAVY WATER, FUEL FABRICATION AND REACTORS

(Subject No 6 in Appendix 3 of Working Report 3 Report)

At its first series of meetings, Working Group 3 invited participants to submit background papers on the subjects of heavy water, fuel fabrication and reactors with regard to supply assurance. The papers subsequently received were distributed by the Working Group as working documents. For the convenience of participants in INFCE and those seeking background information to the INFCE Final Report, the papers are consolidated in the attached documents.

1.	Paper from Federal Republic of Germany	CO-CHAIRMEN/WG3/22 Rev 1
2.	" " Canada	CO-CHAIRMEN/WG3/27
3.	" " Ecuador	CO-CHAIRMEN/WG3/33
4.	" " Federal Republic of Germany	CO-CHAIRMEN/WG3/90

Co-Chairmen/WG 3/22/Rev.1
28. September 1978

INCE WORKING GROUP 3

SUPPLY OF REACTORS

Contribution by the Delegation of the Federal Republic of Germany

I. Introduction

The purpose of this paper will be to provide an outline for the compilation of information on the reactor market, including the policies and practices of reactor suppliers and customers. At present there is only very limited and incomplete information available from published or official sources. Summarized inputs reflecting the policies, practices and experience of both customers and suppliers will be necessary in order to produce a complete and balanced report. Upon completion, such a paper might serve to assess the effectiveness of existing mechanisms and to identify additional or alternative mechanisms for the supply of reactors (and related technology) needed to make nuclear energy widely available as a credible long-term energy source in the interest of national needs, consistent with non-proliferation.

II. Reactor Market

A. Development of the Reactor Market

1. General

At the end of 1977 there were 560 nuclear power plants totalling 437, 539 MWe in operation, under construction or on order in 34 countries (cf. Annex 1). Of these 34 countries 10 have a reactor industry of their own and 24 could be regarded as importing countries. The importing countries' share in the total net capacity (MWe) is about 68,000 MWe or 15.5 %.

There exists a total of 18 nuclear power plant constructors in 10 countries, 8 of which have received export orders so far (cf. Annex 2).

Table 1: Nuclear Power Exports 1956 - 1976
(Orders and Letters of Intent)

	No. of Plants	Capacity MWe	Share %	Capacity installed in supplier's country (1983)	Ratio Export/ installed capacity
USA	55	40,763	66.7	105,000	38.8
Federal Republic of Germany	10	9,632	15.7	24,000	40.0
France	7	5,939	9.7	25,000	24.0
Canada	5	1,731	2.8	12,000	14.4
USSR *)	4	1,680	2.6		
Sweden	2	1,280	2.0		
United Kingdom	2	307	0.5		
	85	61,332	100.0		

*) Exports outside COMECON

2 Supply of medium and small size reactors

Nuclear power stations, as commonly built in industrialized countries, at present range to capacities of 600, 1000 or 1300 MWe using standardized loops as modules. For reasons of technology and, in particular, regional policy it is unlikely that in the near future capacities of 1300 MWe will be significantly exceeded. In many cases such capacities are not appropriate for developing countries because of the size of grids available, and for reasons of planned industrial and regional structure.

300 - 450 MWe reactors represent an important step in reactor development in the industrialized countries and a good many

of them are still in operation. Some of these "reference plants" have demonstrated a high reliability. In addition other reactor types with much lower capacities (approx. 60 - 200 MWe) have been developed for special applications, e.g. ship reactors. Heavy water reactors of 300 - 600 MWe of both the pressure vessel and the pressure tube types are also considered proven technology and continue to be available.

Today plans and construction plans for nuclear power stations ranging between 100 - 350 MWe are being elaborated especially for developing countries on the basis of pressurized water reactors for ship propulsion. These types, however, are not likely to be installed in supplier countries. This results in a possible contradication between the requirement of proveness, including licensing in the supplier countries on the one hand and the special design for the needs and grid sizes of developing countries on the other hand.

Summing up:

Nuclear power stations with capacities up to 600 MWe will be available in the future provided demand is sufficiently high. Preliminary assessments show that a sufficient market volume would consist in approx. 20 nuclear power stations to be ordered in a period of 5 years.

It is unlikely that the comparative cost disadvantages of smaller reactors could be compensated for by shop-fabrication in the fore-seeable future. Although shop-fabrication may reduce the cost of reactor construction considerably in the medium term, such cost advantages would probably be achieved at the expense of domestic industrial development: Standardization always requires the same subcontractor for the same equipment, and the transfer of technology brought about by learning-by-doing, provision of domestic engineering services, domestic plant engineering, production of mechanical and electrical equipment etc., unlikely to be reduced accordingly.

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B. Supply Arrangements

Although the supply of reactors is basically a commercial transaction between the customer and the constructor concerned, it has to be seen in the context of national export/import policies and relevant international agreements.

1. National Policies

a) Export Policies

The export of nuclear reactors (and related equipment) is subject to export licensing regulations. In considering the export of nuclear reactors (and related equipment) it is the declared policy of the Governments of most exporting countries that

i. they will act in accordance with the principles contained in INFCIRC/254;

ii. they are fully aware of the need to contribute to the development of nuclear power in order to meet world energy requirements, while avoiding contributing in any way to the dangers of a proliferation of nuclear weapons or other nuclear explosive devices, and of the need to remove safeguards and non-proliferation assurances from the field of commercial competition.

In addition, some countries will take into consideration other principles considered pertinent by them (e.g. the acceptance by non-nuclear-weapon states of full scope safeguards), and in some countries the export of nuclear equipment is governed by extensive legislation.

b) Import Policies

In respect of nuclear equipment, probably no import policies have yet been defined. Beyond considerations of a merely commercial nature, however, other aspects are perceived to be gaining importanc on the part of importing countries, e.g. non-discriminatory access to nuclear equipment, reliability of supply, sovereignty of importing country.

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2. International Agreements

The supply of nuclear reactors is frequently embedded in an international "umbrella agreement". The scope of such agreements varies fro: case to case; features of such agreements are

i. Safeguards and related provisions
ii. Nuclear cooperation in general
iii. Supporting activities (e.g. exchange of personnel)
iv. Supporting services (e.g. fuel cycle)

There are numerous such umbrella agreements. Their technical scope could be made the subject of a separate analysis, if required. Other than that, two problems seem to be associated with these umbrella agreements:

(a) The need to clarify, rationalise and, if possible, standardize the safeguards (and related) conditions for the supply of reactors. This problem has been outlined in INFCE/WG. 3 / 6.

(b) The extent to which such international agreements are subject to changing circumstances (such as national export legislation). Since this problem affects the supply not only of reactors but also of fuel, etc. it has been proposed as a subject of separate study (No. 1o of INFCE/ WG. 3/ 24 - rev. 1).

3. Supply Arrangements

Commercial arrangements for the supply of nuclear power plants have to take into account the special situation of the customer country: Those who have already a nuclear programme and power plants in operation call for different services than others who just have decided to go nuclear. In the first case numerous examples show that a normal customer/supplier relationship will suffice. In the second case experience has shown that it is not sufficient just to deliver a nuclear power plant; in addition the transfer of know-how concerning for instance, the operation of power plants or nuclear licensing has proved necessary. Therefore, the supply of nuclear power plants to countries with only modest nuclear programmes normally requires the involvement of many different partners, e.g. governements, private industry, licensing authorities, research organization etc.

The following paragraphs outline the various arrangements normally employed for the supply of reactors.

a) Normal Customer/Supplier Relationship

In general, arrangements differ only in scope of supply and degree of liability:

- Supply contract: restricted to components; very limited supplier's liability.

- Turnkey Contract: includes all components and services for the construction of the nuclear power plant including the guarantee of its proper functioning; this does not imply that the turnkey contractor places the orders with foreign suppliers: orders can be given also to domestic suppliers depending on the level of domestic industrial infrastructure and the availability of domestic qualified manpower.

  Advantages: High supplier's liability, small risk for the costumers as far as technical and financial aspects are concerned.

  Disadvantage: Turnkey contracts as described here are only available from a limited number of suppliers.

- Semi-Turnkey Contract: includes supply of equipment, plant design and project management; it may additionally assume construction and plant erection on the basis of reimbursable costs, that is for an unquoted price.

- Engineering contract: restricted to engineering services for a project, no supply of components; liability similar to architect engineer contracts.

Arrangements cover the following components and services:

- Nuclear Steam Supply System
- Turbo-Generator
- Balance of Plant
- Civil works, conducted by local enterprises if possible
- Infrastructure
- Supplies and services normally to be provided by the customer as, for instance, site selection and preparation
- First core and reloads, if desired
- Maintenance contracts.

b) Customer just embarking on a nuclear power programme

In such cases comprehensive cooperation with the customer and a high degree of supplier's involvement might be of advantage. According to the experiences gained so far, it is reasonable to develop this type of cooperation in stages.

Stage I

Agreement between the governments of the countries concerned, providing the frame work for joint scientific research and development. Such agreement will set out the areas of cooperation according to the specific needs of the customer country.

Stage II

On the basis of a Stage I umbrella agreement, detailed implementing arrangements will be concluded. Cooperation will be arranged between corresponding research establishments, universities, institutions, licensing and inspection agencies,etc. in the respective countries in order to investigate whether and how nuclear energy could make a significant contribution to the future energy supply of the customer country.

Stage III

Industrial cooperation may take any of the forms outlined in paragraph (a) above. Usually it goes along with a scheme for the transfer of know-how by means of exchange of information, licensing agreements, training of personnel, industrial subcontracting or industrial joint ventures, and covering areas like nuclear licensing procedures, reactor safety concepts and procedures, operation and maintenance of nuclear power stations, etc.

4. Guarantees for Assuring Supply and Demand and Back-up Arrangements in the Event of Production or Demand Breakdown.

This aspect seems to relate to the supply of fuel and services rather than to the supply of reactors and related equipment.

5. Factors Affecting Market Stability.
As compared with previous years, the demand for reactors has declined sharply during 1975-77 (Annex 2). This is frequently attributed to revised energy demand forecasts or to the changes in public opinion towards nuclear energy (see subject No. 3 in INFCE/WG. 3/24 - rev. 1).

Another aspect affecting the supply of reactors is the growing concern of countries not having a full nuclear fuel cycle (see subject No. 9 of INFCE/WG. 3/24 - rev. 1). It impacts on the supply of reactors in two ways:

(a) Supply of fuel

Countries having to rely on the import of uranium and related services need to be convinced of having a long-term assurance of supply before they decide to invest in nuclear power plants. In recent years prospects of obtaining reliable assurances in this respect have become somewhat dubious (divergence of views on world uranium reserves, supply interruptions). Moreover, if important consumer countries decide not to reprocess and recycle unused uranium and plutonium, the world uranium market may grow even tighter, so that such a decision could have a negative effect on countries depending on the import of uranium and related services.

(b) Disposal of spent fuel

Closing the back-end of the fuel cycle (storage, reprocessing, waste disposal) has become a prerequisite in some countries for the granting of new construction licenses for nuclear power plants.

In this situation potential customers especially in countries with a limited or small nuclear power programme show an increasing tendency to ask their reactor suppliers for the provision of the associated fuel cycle services. This may be a convenient means to overcome present difficulties or concerns. Its long-term implications would merit, however, further comment and analysis, e.g.

- Since suppliers of reactors may have different fuel cycle policies and concepts, customers having opted for a particular reactor supplier may find it difficult to rearrange their fuel cycle at a later stage (limitation of choice).

- It is unlikely that a proper international solution for the back-end of the fuel cycle will emerge from different - and sometimes contradictory - bilateral agreements or ad hoc arragements designed for the supply of reactors.

C. Effectiveness of Existing Arragements for the Supply of Reactors

Analysis to be undertaken on the basis of inputs, in particular from customer countries.

III. Multinational or International Mechanisms Guaranteeing Timely Deliveries in Case of Delay or Cut-off of Supplies

This aspect seems to relate to the supply of fuel and services rather than to the supply of reactors and related equipment.

Annex 1

Distribution of Nuclear Power Plants (End of 1977)

Country	In Operation	Net Capacity MWe	Under constr. or ordered	Total Net Capacity, MWe
Argentina	1	319	1	919
Austria	-	-	1	695
Belgium	4	1 660	4	5 560
Brazil	-	-	3	3 206
Bulgaria	2	840	2	1 680
Canada	9	4 752	15	15 405
Czechoslovakia	1	110	4	1 710
Finland	1	440	5	2 980
France 1)	12	4 640	29	33 084
Federal Republic of Germany	14	7 025	17	25 643
German Democratic Republic	3	960	4	2 720
Hungary	-	-	2	800
India	3	580	5	1 580
Iran	-	-	8	9 006
Italy	3	597	6	5 300
Japan	14	7 994	15	13 857
Republic of Korea	1	605	2	1 764
Luxembourg	-	-	1	1 300
Mexico	-	-	2	1 320
Netherlands	2	498	-	498
Pakistan	1	125	-	125
the Philippines	-	-	2	1 252
Poland	-	-	2	880
Puerto Rico	-	-	1	560
Romania	-	-	1	440
Sweden 1)	6	3 770	6	9 459
Switzerland	3	1 006	4	4 806
South Africa	-	-	2	1 844
Spain	3	1 073	17	17 662
Taiwan	1	636	5	4 920
United Kingdom 1)	21	5 132	7	9 457
USSR	26	7 779	16	20 579
USA 1) 2)	64	45 443	175	235 873
Yugoslavia	-	-	1	615

1) The following plants are not included in the table; Federal Republic of Germany: KKN, HDR; France; Chinon I; UK: DFR; Sweden: Agesta; USA: Peach Bottom - 1

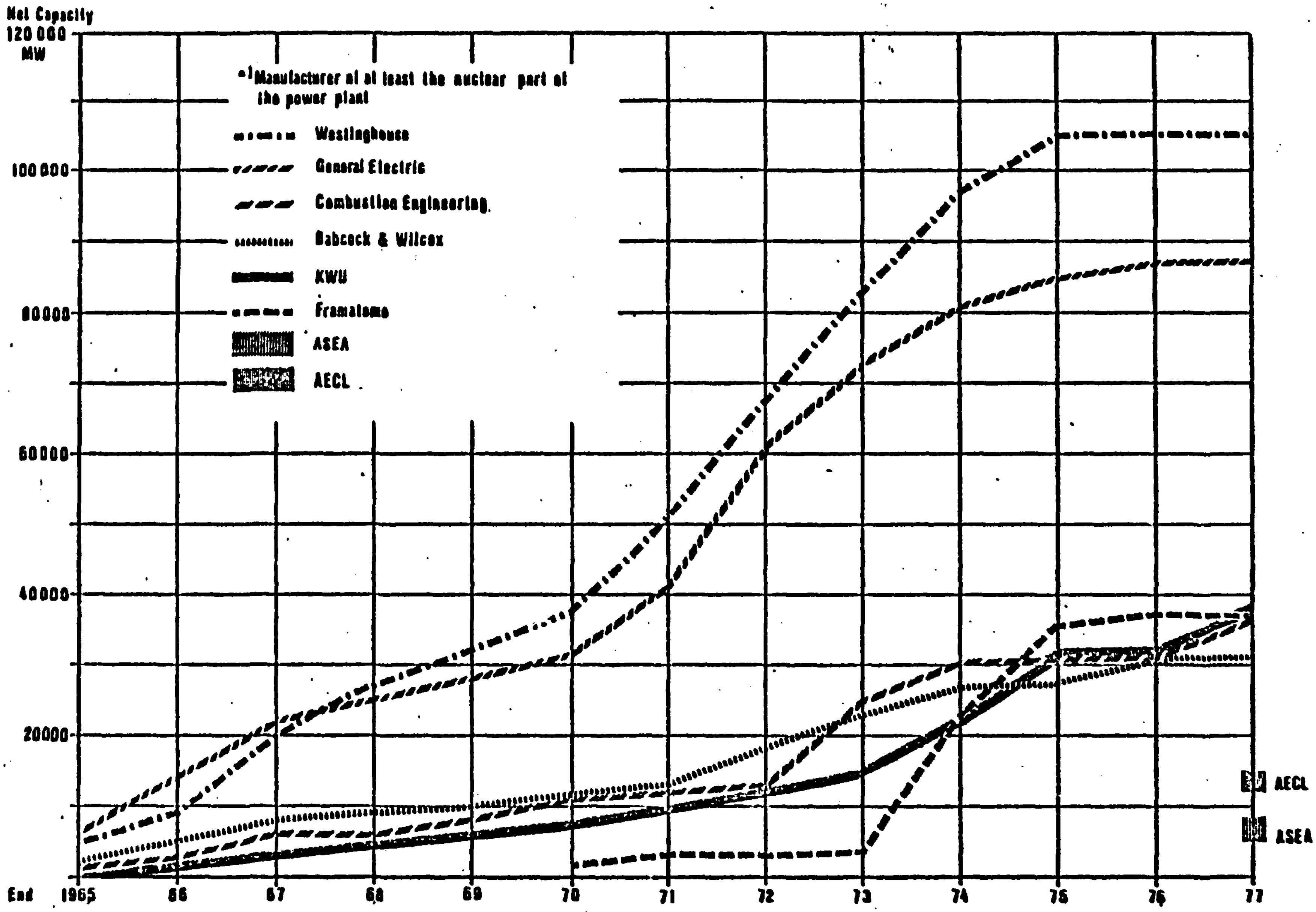
2) In the case of the USA, orders are included which have been postponed for the moment: 27 plants, i.e. 27, 861 MWe

Source: Atomwirtschaft, March 1978

Annex 2

Accumulated Orders on Nucl. Power Plants of Different Manufacturers *)

(in MW, until End of 1977) without cancelled orders



April 7, 1978

INTERNATIONAL NUCLEAR FUEL CYCLE EVALUATION
WORKING GROUP 3

DISCUSSION PAPER PREPARED BY CANADA
ON HEAVY WATER PRODUCTION AND SUPPLY

INTRODUCTION

Although heavy water, like reactor fuel, is an essential component of the heavy water reactor power package, there are certain characteristics of heavy water different from those of reactor fuel which significantly affect the supply assurance question.

NON-PROLIFERATION FACTORS

Because of its fundamental importance to heavy water nuclear reactors, heavy water and the means of its production have attracted safeguards in the Zangger Trigger list INFCIRC 209 (heavy water only) and the Supplier Guidelines INFCIRC 254 (includes heavy water equipment and manufacturing technology). In addition, as a matter of national policy, some nations have required bilateral controls on the material, equipment and technology related to heavy water and its production.

It should be noted, however, that heavy water technology (and associated equipment and product) is in a category different from the other "sensitive" technologies identified in INFCIRC 209 and 254 in that it cannot by itself lead to the production of nuclear explosive material. Uranium enrichment by itself can produce nuclear explosive material; reprocessing combined with a supply of spent fuel can produce nuclear explosive material. In contrast, heavy water is sensitive only when coupled with reprocessing.

TECHNICAL CHARACTERISTICS AFFECTING SUPPLY CONCEPTS

The most important characteristic affecting heavy water production and supply is that demand for heavy water is directly related to heavy water reactor <u>construction</u> and is not significantly related to heavy water reactor <u>use</u>. Unlike fuel, heavy water is not consumed during reactor operations. Once supply has been arranged for the initial charge, there is no further need to contract for large quantities other than those required to service future reactor commitments. In this sense, heavy water must be considered part of the component supply of the reactor. Typically, CANDU reactors require a supply of about 0.8 megagrams per net MWe out.

Normally heavy water is not required at the construction site until reactor construction is essentially complete - typically 15 months prior to first production of power. Nevertheless the reactor cannot operate without the heavy water and its supply should be assured as part of the overall reactor commitment. Therefore security of supply and timely delivery of the initial charge are important. Once the initial charge has been delivered, the only continuing supply necessary for operation of the reactor is that required for routine make-up and such quantities as may be needed to replace accidental loss.

Regarding make-up, experience with heavy water reactors (CANDU) indicates that loss from normal operation requires less than 1% per annum of the initial charge. What little downgrading of heavy water occurs at the reactor site is normally handled by small, on-site upgrading units. Under good management, the original charge plus a modest additional inventory to cover make-up of predictable losses during operation is adequate. In this sense, the question of supply assurances for heavy water differs significantly from that with regard to fuel supply inasmuch as the supply of heavy water is not a recurring requirement. Because there is no global shortage of heavy water, contracts related to reactor construction are all that is required to assure heavy water supply.

Heavy water reactors are well instrumented to detect heavy water leakage and hence major accidental losses are unlikely. Nevertheless some losses may occur through operating errors or by accident and will normally be replaced out of established reserves.

It is noteworthy that since heavy water is not consumed in the course of reactor operation, it constitutes a major recoverable asset at the end of reactor life, available to commission new reactors.

HEAVY WATER SUPPLY MANAGEMENT

By far the major commercial demand for heavy water derives from the needs of nuclear power programmes. Reliable projections of future heavy water reactor construction are therefore essential for good heavy water supply management. Given reliable projections of demand, the planning for supply of heavy water then requires consideration of three factors:

a) the production levels at existing and new plants

b) the optimum time to increase production capacity

c) need for reserve inventories against emergency demand situations.

a) Existing and Committed Production

The production of reactor-grade heavy water depends on both design capacity of the plant and the reliability of both the plant and its energy supply. Since the cost associated with the shortfall in supply in terms of lost electrical production greatly exceeds the cost of a heavy water surplus in terms of carrying costs, conservative assumptions on production rates should be used. Operating experience in mature plants suggests that planning should be based on production levels which have a 90% chance of being exceeded. Typically this level of assurance establishes a production base which is forecast at 60 to 65% of the design capacity. From this base, reliable production capacity can be incrementally increased through operating experience, plant improvements and fine tuning. Because heavy water production plants are capital intensive and their product is of critical importance to power production, the need for a strong technical support base to achieve high plant reliability and capacity factors is evident.

b) Increased Production Capacity

Heavy water can be produced by a number of well known processes. However the only process which has been brought to large scale commercial maturity is the Girdler-Sulphide process. Experience indicates that a reasonable unit size is one of 400 megagrams design capacity per annum. Hence the planning of new production capacity becomes a trade-off between the cost of establishing large inventories in the short term and the limits of allowable risk in meeting reactor needs. Increased heavy water production capacity is not required to support the constant expansion of a reactor system. This is in contrast with the fuel supply situation in which a constant growth in reactor system requires a corresponding increase in growth of fuel supply.

c) Reserve Inventories

In view of the large costs associated with loss of energy production, it is evident that a reserve inventory should be available to meet unforeseen production shortages and emergency reactor requirements. However, heavy water inventories are expensive to maintain and as such contribute to the overall costs of energy production.

In countries in which the reactor base is small, the establishment of large insurance inventories may not be economically attractive. On the other hand, it is unlikely that heavy water suppliers would develop additional standby heavy water capacity or reserves to meet emergency demands for which they are not contractually bound. Clearly the question of reserve inventory is a matter for resolution contractually between suppliers and users.

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EXISTING SUPPLY ARRANGEMENTS

Commercial heavy water production has now matured and has reached a level of reliability which allows management of heavy water supplies at a high level of confidence. Sufficient production capacity is now committed to meet known world needs into the 1990's. Demand beyond that period can be met by new construction as required. The lead times for additional production capacity closely approximate that for nuclear electrical requirements. Provided that firm commitments are available with reasonable lead time, heavy water supply assurances for nuclear systems based on heavy water will not be a matter of concern.

CO-CHAIRMEN/WG.3/33
21 April 1978

STUDIES ON SMALL AND MEDIUM SIZE NUCLEAR POWER PLANTS

Statement submitted by the delegation of Ecuador for consideration by Working Group 3 of INFCE

April 1978

During recent years there has been a definite trend in the development of nuclear power plant projects towards building stations of increasingly large size. Most of the generating units being installed, and some of those which are already in operation, have capacities exceeding 1000 MW and even 1200 MW.

One of the determining factors in this process is the effect of economies of scale on the unit cost of power generation, a matter which is of particular importance in this case owing to the great complexity of the components of nuclear power plants compared with those of more conventional plants. Furthermore, the absolute values of the increase in the demand for electricity in the advanced countries is such that their networks can readily assimilate intermittent peaks of large size, thereby creating a demand market for units of high power.

In this last respect, the situation is completely different in the small countries. For many the absence of supply of small nuclear plants simply means an indefinite postponement of their access to this source of energy.

This would not be of major importance if the future supply picture presented a broad range of available alternatives. We all know, however, that this is not the case and that in all probability mankind as a whole will have to consider nuclear energy as the decisive source of energy during the next few decades. Accordingly, the non-availability of small power plants on the market may mean a further setback in the advance of a majority of the world's peoples and a further frustration of their desire for progress.

In these circumstances, it must be asked whether the considerations as to the economic competitiveness of nuclear energy, which have been partly responsible for this trend towards large power plants, are still valid for the new energy situation which the world has had to cope with since 1973.

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Ecuador, which is seriously concerned over this question, wishes to suggest to INFCE the necessity for intensification of its action in the above presented matter.

The minimum economic module of a nuclear power station is not an immutable constant and depends to a very large extent on the cost of alternative energy sources, the special geographical features of each installation and the new possibilities to which research and development efforts give rise.

In view of the foregoing, Ecuador proposes:

1. That these estimates be regularly and continuously updated in the light of changing market conditions; and
2. That INFCE take steps, in the framework of the developmental laboratories of the major countries and the commercial manufacturers of power plants, to stimulate interest in the market to which the above considerations would give rise and that it assist in overcoming the technical difficulties which might be involved.
3. That INFCE undertakes a study on means to finance the development of nuclear power plants between 400 and 600 MW(e) as well as plants of a lower yield.

Ecuador is aware that IAEA and now INFCE have initiated studies on these problems in the past years. The cooperation of all Member States is required to give this matter priority attention.

CO-CHAIRMEN/WG 3/90
28. September 1978

INFCE WORKING GROUP 3
FUEL FABRICATION SERVICES

Contribution by the Delegation of the Federal Republic of Germany

1. GENERAL

The fabrication of fuel assemblies (in this case for LWRs) basically comprises four important steps of fuel processing. Low-enriched UF_6 is converted into uranium oxide powder. The UO_2 powder is then homogenized and compressed to form pellets. The subsequent sintering step at temperatures exceeding 1,700°C imparts the required density and stability to the pellets. The UO_2 pellets are hermetically encapsulated in special cannings. By means of structural components the fuel rods obtained are assembled to form fuel assemblies.

The fuel assembly normally achieves the design burnup after 3-4 year residence time in the reactor and has to remain intact and to work without problems. It also has to offer the possibility of being stored without leakage over many years.
As a rule the initial loads and the first reloads are provided by the reactor manufacturers. The supplier guaranties the mechanical integrity of the fuel assemblies during their usual in-service-time.

1.1. SUPPLY

The fabrication of fuel assemblies represents an advanced technique which by now is mastered by a number of firms in industrialized countries (see Table 1)

Table 1: **Fuel Assembly Suppliers**

Fuel Assembly Supplier Uranium	Capacity (t U/a) powder	pellets	pins	Remarks
USA				
General Electric	1000	1000	1000	only BWR
Westinghouse	1150	1150	1150	only PWR
Combustion Eng.	150	150	250	
Exxon	150	150	150	
Babcock & Wilcox	360	375	375	
Europe				
ASEA (Sweden)	400	400	400	
BNFL (U.K.)	600	600	125	
Coren (Italy)	-	-	60	
ENUSA (Spain)	-	-	-	approx. 800 pins in 1985
Exxon (Germany, F.R.)	-	-	-	approx. 120 t powder + pellets 79 t
FN (Italy)	-	200	200	planned amount in powder 200-400 t
FBFC (Belgium)	-	200	200	planned amount in powder 200-1000 t
FBFC (France)	-	-	200	planned amount in powder 200-600 t
RBU (Germany, F.R.)	1000	750	750	extension will be planned
Japan				
INF	-	490	490	
MNF	-	420	420	
NFI	12	40	40	planned 60-140 t
others				
Nuclebras (Brazil)				planned amount in 1980 - 1985 approx. 100 - 400 t
NFC (India)				
Westinghouse (Canada)				

1.2 DEMAND:

The annual short-term world demand for fabrication of nuclear fuel is listed in Table 2.

Table 2: WORLD FUEL FABRICATION REQUIREMENTS, 1977 - 2000

1,000 tonnes U

YEAR	"ACCELERATED" POWER GROWTH		"PRESENT TREND" POWER GROWTH	
	ANNUAL	CUMULATIVE	ANNUAL	CUMULATIVE
1977	4	4	4	4
1978	5	9	5	9
1979	6	15	6	15
1980	7	22	6	21
1981	9	31	7	28
1982	10	41	8	36
1983	12	53	9	45
1984	13	66	10	55
1985	15	81	11	66
1986	17	98	13	79
1987	19	107	14	93
1988	22	129	16	109
1989	25	154	17	126
1990	28	182	19	145
1991	31	213	21	166
1992	35	248	22	188
1993	39	287	24	212
1994	43	330	26	238
1995	48	378	28	266
1996	53	431	30	296
1997	57	488	32	328
1998	63	551	34	362
1999	70	621	37	399
2000	74	695	38	437

Source: OECD/NEA, "Nuclear Fuel Cycle Requirements
and supply considerations,
through the long-term", February 1978

2. LONG-TERM ASSURANCE OF SUPPLY

In view of the now existing and foreseeable capacities the world-wide supply of LWR fuel elements is assured until 1985. This applies equally for intermediate steps down to chemical conversion. Fig. 1 shows the growth to capacity needed in relation to the demand by the year 2000.

Figure 1:

World Annual Fuel Fabrication Requirements, 1977 - 2000

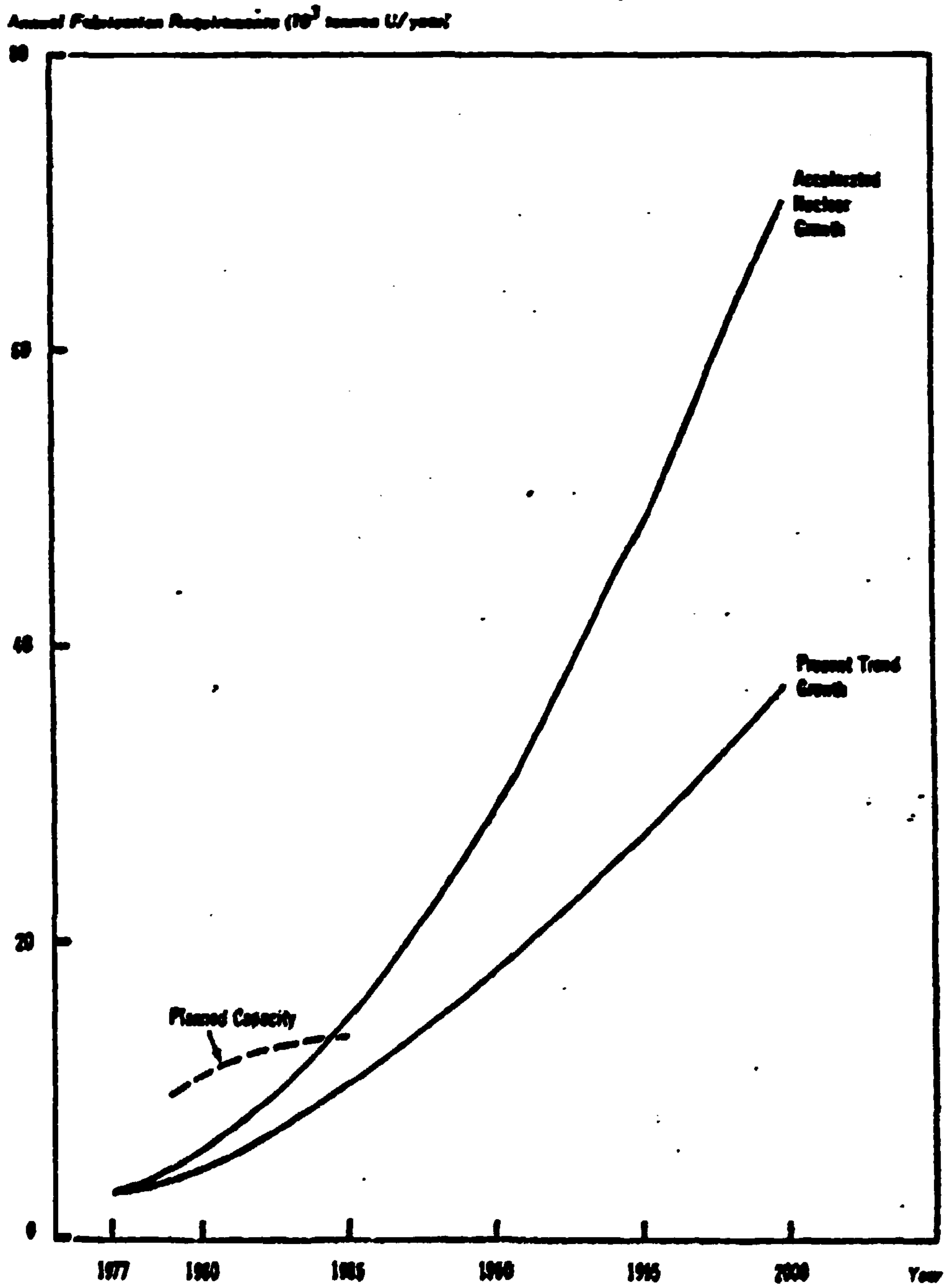

Figure taken from:

OECD/NEA "Nuclear Fuel Cycle Requirements and Supply Considerations Through the Long-Term, February 1978

A continuos growth of the fuel assembly fabrication capacities could be secured without serious problems unless there are significant delays through licensing procedures.

Fuel assembly fabrication is one of those productions which can be taken up at a relatively early stage of the setup of a domestic nuclear fuel cycle. So far supply problems have not arisen in the fabrication process itself, but rather in the supply of inputs, in particular U_{nat}, $U_{enr.}$ or zircaloy for cannings. (As far as the supply situation with U_{nat} and $U_{enr.}$ is concerned, we refer to the Britisch (Co-Chairmen/WG 3/18) and American (Co-Chairmen/ WG 3/23) papers . The situation prevailing in the zirconium sponge market is characterized by a very small number of suppliers.* Recently delays in delivery for non-proliferation reasons have occurred.

3. HEU FUEL ASSEMBIES AND Pu FUEL ASSEMBLIES

3.1 HEU FUEL ASSEMBLIES:

HEU fuel assemblies are usually used for high temperature reactors, research reactors and fast breeder reactor experiments. There are no unsolved technical problems in the fabrication of highly enriched uranium fuel assemblies.

The HEU fuel assemblies supply depends on the HEU deliveries. For political reasons there have lately been some delays in the supply of HEU which could and can only be overcome with great difficulies. As far as reactors have no alternative to the use of highly enriched uranium, larger delays or a stop of deliveries would lead to their shutdown.

3.2 Pu FUEL ASSEMBLY

The Pu fuel assembly fabrication requires more than the processing of uranium in the field of very sophisticated and advanced technologies. Nevertheless, it does not involve any unsettled technical questions. As for existing or planned capacities s. Table 3.

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*At present only limited and incomplete information is available concerning zirconium sponge capacities and zircaloy canning fabrication capacities. Further information would be welcome.

Table 3:

Pu-Fuel Element Facilities

Supplier	Annual Capacity	Date of Operation	Situation
Europe			
BNFL (UK)	PuO^F: 10 $MTUO_2$- PuO_2/Yr		(1)
CEA (France)	$UO^F PuO^F$: n.a.		(1)
ALKEM (Germany, R.F.)*	PuO_2-UO_2 for LWR : 24 t/Yr	1972	(3)
	PuO_2-UO_2 for FBR: 3 t/Yr		
FBFC (Belgium)	UO^F: 200 MTU/Yr		(1)
	$UO^F PuO^F UC^F PuC^F$: 30 $MTUO_2$-PuO_2/Yr		
CNEN (Italy)	UO^F-PuO^F: 1-5 t/Yr	1968	(4)
SF (Italy)	UO^F-PuO^F: 14 t/Yr	1982 (planned)	(2)
USA			
Rockwell International	U^{MF}/Pu^F : n.a.		(1),(4)
G.E.	Pu^F : n.a.		(4)
Kerr-McGee Nuclear Corp.	$UO^F PuO^F$: n.a.		(3)
NFS	$UO^R PuO^R$: 300 t/Yr		(3)
Babcock and Wilcox	PuO^F/PuC^F : n.a.		(1),(4)
W.H.	Pu^F : n.a.		(2)
Japan			
PNC	PuO^F : 10 t PuO_2-UO_2/Yr, ATR	March 1972	(4)
PNC	3 t PuO_2-UO_2/Yr, FBR	Nov. 1972	

*In contrast to the original source the German capacity is corrected.

Based on:
H. Fujii/IAEA,
Nuclear Fuel Cycle
Facilities In The World,
May 1978

Key to fuel cycle symbols:

UM^F: U metal fabrication

UOF: U oxide fabrication

PuO^F: Pu oxide fabrication

UC^F: U carbide fabrication

PuC^F: Pu carbide fabrication

UO^R: U oxide reprocessing

PuO^R: Pu oxide reprocessing

(1) Plant operating

(2) under construction or planned

(3) Initiative or on standby

(4) Pilot or laboratory facility