FRENCH EXPERIENCE IN ACHIEVING NUCLEAR POWER SELF-RELIANCE AND POSSIBLE BENEFITS FOR INTERNATIONAL COOPERATION

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ABSTRACT

The success of France's nuclear power program can be attributed to two main factors :

- The necessity for France to increase its energy independence. Nuclear energy was the only viable choice, but French industry had to master all the phases of such a program.

- A will to pursue the objectives set, which has remained steadfast for over 20 years.

Today, two-thirds of French electricity comes from nuclear power, and the French program is continuing its regular progression.

Several times already, in particular in this Pacific basin region, French industry has cooperated in nuclear power projects abroad. It is convinced that even greater international cooperation can only be beneficial for all, and is ready, for its part, to bring to bear on this effort all of its experience and resources.

INTRODUCTION

The year 1986 shall remain, in the world of energy, the year of two major occurrences : consistently low oil prices throughout the year and, in April, the Chernobyl nuclear power plant accident.

Faced with such developments, both world public opinion and decision makers had the normal reaction of doubts as to what general lessons to draw and as to the future of nuclear energy. This was one of the main questions debated at the World Energy Conference held in Cannes, France last fall. The general feeling that came out of that discussion was that nuclear power is still and shall remain a commercially viable, reliable, safe, and essential source of electrical energy for the next century.

Nevertheless, in the immediate future, the predominant trends are those of indecision and waiting. Numerous nuclear power programs have been stopped and projects suspended, awaiting the return of a more favorable environment.

In the midst of this gloomy picture, the French nuclear power program shines brightly by its success and vitality. In France, six new nuclear power units were connected to the grid during the past year : Chinon B3, the next-to-last of the series of 34 900-MWe units ; Paluel 4, Saint-Alban 2, Flamanville 2, and Cattenom 1, four additional 1300-MWe units, and Superphenix, the 1200-MWe fast breeder reactor plant at Creys-Malville.

The installed power of the 49 French nuclear power units now in service attained 45,000 MWe, thus increasing the country's nuclear-powered electrical generation capacity by 19 % during the year.

More specifically for Framatome, 1986 was the year of the Guangdong plant contract. At the same time that international competition reached new heights, the People's Republic of China (PRC) confirmed its confidence in French nuclear power technology.

There has been talk of a future, short-lived overcapacity of the French nuclear power program, but any such overcapacity can be mostly attributed to the extremely high availability factors of Framatome pressurized water reactors (PWRs). Their average energy availability has been above 83 % for each of the last three years, far beyond the forecast 71 %.

At present, France is the only country in the world with such a coherent and dynamic nuclear power industry. It is also the only one to have carried out such a massive and continuous nuclear power program, which is continuing to go forward.

Let me assure you that it is not just to brag that I mention this French success. Instead, I want to propose it as an example that can give confidence in the possibilities and potentialities of nuclear energy, to analyze the reasons for this success, and perhaps to draw from it some strong motivations to develop and intensify a beneficial international cooperation, especially with the countries that are represented at this Conference.

Before analyzing it in more detail, it is important to first underline and emphasize two of the keys to this success :

. First, a will to acquire the greatest energy independence by achieving self-reliance in all the aspects of nuclear energy (research, design, construction, and operation of nuclear power plants ; and mastery of all the stages in the nuclear fuel cycle).

. Second, an unfailing commitment, over many years, to pursuing and realizing this objective.

FLASHBACK ON THE HISTORY OF NUCLEAR POWER IN FRANCE

The story of nuclear power in France is a long one, and to understand it one has to go back to the beginning. Nuclear research in France began with the discovery of radioactivity by Henri Becquerel and that of radium by Pierre and Marie Curie. Thirty years later, Frédéric Joliot-Curie demonstrated the feasibility of sustaining a nuclear chain reaction and applied for the first nuclear reactor patents. Immediately after the Second World War, in 1945, General de Gaulle created the French Atomic Energy Commission (CEA).

Already at that time the foundations were being laid for what was to become and remain the solid framework within which nuclear power has been developed in France.

. The processes involved in all of the stages of the nuclear fuel cycle were developed and implemented.

. The first reactors were designed and built by French industry. At that time they were mainly natural-uranium fueled, graphite moderated, and gas cooled.

. But they were also, illustrating the degree of progress already made, the first fast breeder reactors (FBRs), such as Phénix, a 250-MWe FBR whose regular operation began in the early 1970s, over 15 years ago.

. In parallel, at Chooz, Framatome constructed a plant of an entirely different model, with a 300 MWe pressurized water reactor that used enriched uranium fuel.

THE MAJOR GUIDELINE DECISIONS

All of these achievements enabled the participants to acquire experience and competence that were precious when, a little later, the French nuclear power effort was inflected by a set of major decisions that led to the growth and results visible today.

It was in 1973 that the French governmental authorities decided to move full speed ahead on nuclear energy. Their reasoning was clear : France has very few natural energy resources, and has had to rely heavily on imported energy supplies, in particular oil. The challenge was therefore to improve, to the greatest extent possible, French energy independence by developing "national" energy sources.

To meet such a challenge, nuclear power offered the only viable solution at that time. To avoid escaping from one dependency only to fall into another one, however, development of nuclear energy had to be conducted in a way that allowed France to fully control all of its aspects, including the entire fuel cycle and the design, construction, and operation of its future nuclear power plants.

Let me remind you of the basic decisions made back in 1973 when the French authorities launched this vast program :

. A large number of plants would be built, but employing only one technology. The natural uranium gas-graphite approach was eliminated for economic reasons and, after careful evaluation, the decision was made to go with PWR technology.

. The necessary industrial capacities would be mobilized and concentrated in the hands of only a few companies. These companies, assured of program continuity and a stable market, would be encouraged to make the necessary investments in human resources and industrial facilities to ensure program success.

. A complete and consistent set of codes and standards would be established, to facilitate regulation.

. Finally, the program would include large series of identical units, so that standardization could provide the best compromise between two important objectives :

. First, technical stabilization over as long a period as neccessary to obtain the expected benefits from the series effect ;

. Second, remaining open to improvements due to technical progress and experience feedback.

STEP-BY-STEP PROGRESS THROUGH STANDARDIZATION

To achieve this objective and to avoid the risk of successive and not always fully justified design changes, France has chosen the path of "step-by-step evolution". This is done by means of successive plant series, each of which corresponds to an updated standard. Therefore, each series represents one step ahead in the technical evolution, and benefits from the experience gained during the previous step.

Let me now briefly identify these successive series.

The 900-MWe series :

Based upon a twin-unit configuration, this series of three-loop nuclear steam supply system (NSSS) design began with the two units at Fessenheim, contracted for in 1970, and the four units of the Bugey plant, contracted for in 1970 and 1971.

The experience gained in designing these six units led EdF to then launch two large series of standardized 900-MWe class units :

. The CP1 series, comprising 18 units, ordered in 1974. They are built as twin units, with a common turbine hall and nuclear auxiliaries building.

The CP2 series, comprising 10 units, ordered in 1977. They are similar to the CP1 units, but with a separate turbine hall for each unit, layed out in the radial direction from the reactor building.

The 1300-MWe series :

The series, launched in 1976, consists of 20 four-loop units of a larger size, well suited to the present-day French power grid. It includes two standard subseries :

. The P4 subseries, eight units in all ; and

. The P'4 subseries, with 12 units, similar to the P4 units, but with more-compact buildings, resulting from civil works optimization.

And finally, the 1500 MWe or "N4" series :

Two units of this most recent series of four-loop design have already been ordered by EdF. They correspond to the latest developments in French nuclear power technology, with a new-model steam generator, new reactor coolant pumps and steam turbines, and advanced instrumentation and control.

PRESENT STATUS OF THE FRENCH PROGRAM

Summarizing the current status of the French nuclear energy program :

. Thirty-two units of the 900-MWe class are in commercial operation, one more is on line but not yet in commercial use, and the last one is in the final stages of construction.

. Nine 1300-MWe units are in operation, with 11 more in various stages of completion.

. And the first two 1500-MWe units are now under construction, with four more being currently planned.

When all of these units are in operation, over 75 % of the electricity produced in France will be of nuclear origin. In 1986, more than two-thirds of the total French electricity generation was already due to nuclear power, compared to only 8 % in 1974.

Cost Considerations :

Supplementary to the achievement of energy independence, France's "nuclear option" turned out to be a financial success and to be highly advantageous in terme of the cost per kilowatt-hour. The following table shows the costs of one kWh in France, generated by nuclear, coal, and fuel oil thermal power plants, broken down into :

. capital cost
. operation and maintenance cost, and
. fuel cost.

POWER GENERATING COSTS

BASED ON CURRENT 1986 COAL AND OIL PRICES

— COMMISSIONING DATE : 1992
— CURRENCY UNIT : FRENCH CENTIME AS OF JANUARY 1, 1986
— ECONOMIC LIFE : 25 YEARS

	NUCLEAR	COAL	OIL
CAPITAL COST	12.1	8.2	6.8
O AND M COSTS	4.3	3.5	3.0
FUEL COSTS	6.4	16.9	32.7
TOTAL	22.8	28.6	42.5

These figures reflect the clear cost advantages of nuclear power plants in France. Although the prices of coal and oil have substantially fallen in 1985 and 1986, it can be seen that the "nuclear" kWh is considerably cheaper than the kWh produced from oil and remains competitive with coal.

Construction Time

The experience acquired over the past 15 years has provided complete mastery of the problems of nuclear power plant construction. Thus it has been possible to control and reduce the unit construction times from the start of erection to commissioning.

In 1978, it took over 48 months from the start of piping erection to the commissioning of Fessenheim 1. Since 1983, this period has been cut to 31 or 32 months for Framatome PWR units. Moreover, quality has been simultaneously improved. Today, the state of readiness of new units at initial core loading is comparable to that of older units having already operated for several years.

Availability

Altogether, Framatome's PWR units now have over 200 reactor-years of successful operation behind them.

The availability of these units has regularly increased. The overall "energy availability factor" for 900-MWe French PWR units in commercial operation was 83.2 % in 1984, 84.3 % in 1985, and again over 83 % in 1986, a remarkable and unsurpassed performance for three years running and a tribute to the excellent EdF operating staff.

FRENCH NUCLEAR INDUSTRY ORGANIZATION

The success of the French nuclear power program can be attributed to several factors. The first, as I mentioned previously, is the definition of a clear national energy policy, consistently carried out by all the succeeding governments. The execution of this policy is backed by an administration conscious of its responsibilities, inflexible on safety, determined to protect the environment, but animated by a will to succeed and efficient in carrying out its tasks.

Another factor, just as important, is the highly centralized French nuclear industry structure that has been created. This structure made it possible for the enterprises involved to concentrate their efforts, to make the necessary investments, and share out the jobs to be done, without multiplying rivalries of duplicating each other's work.

Electricite de France (EdF), the national electrical utility, is the plant owner, prime contractor, and operator.

The French Atomic Energy Commission (CEA) performs part of the research and development and provides the necessary technical support to the safety authorities.

A few leading industrial firms design and manufacture the major parts of the nuclear power plants. Framatome is responsible for the design, manufacture, erection, and startup of the NSSSs, its fuel elements, and related auxiliaries. Alsthom supplies the turbine and its auxiliaries.

Cogema provides natural and enriched uranium fuel for the reactors and reprocesses the spent fuel after its use.

For export projects, Framatome can supply the complete nuclear island and Alsthom the complete conventional island. In this way, the French nuclear power industry handle all types of situations, from NSSS supply to ready-to-operate turnkey plants.

THE FRAMATOME STORY

To build such a large number of nuclear power units as quickly as France has done (up to six per year), Framatome, its affiliates and its subcontractors had to build up and adapt their industrial capacities in record time. An outstanding example is the Framatome heavy component factory at Chalon-sur-Saône, a European showcase because of its modern equipment and high production capacity. In all, in only a few years Framatome created the potential to produce the key components for up to eight nuclear units per year : eight assembled reactor vessels, 18 to 24 steam generators, depending on the unit model, and eight pressurizers.

Based on the already discussed French nuclear program, and aided by the powerful R & D capabilities of the CEA, Framatome's own R & D program enabled the company to achieve full technical and technological independence.

Between 1st january 1980 and 30th september 1986, a total of 44 nuclear power units were ordered in the world. Framatome won 22 of these orders, the last one being for two 1000-MWe class units for the Daya Bay site in China. The contract was formally signed on 23rd September 1986.

BENEFITS FOR INTERNATIONAL COOPERATION

Mention of this contract leads naturally into the subject of how France's experience in nuclear energy could be put to the profit of other countries.

By way of introduction, it should be noted that from the beginning one of the main objectives assigned by the French authorities to the participating industrial companies was that the facilities set up in France for its national nuclear power program be suitably dimensioned to enable assisting any other country that wanted to cooperate with France.

Under these conditions, it is clear that we are ready to devote our resources and our experience to expanding international cooperation in the nuclear energy field. Not only are we ready to do so, but we are capable of so doing, as we have already successfully demonstrated in Belgium, South Africa, and the Republic of Korea. Today, we are engaged in a similar effort in China, for the construction of two complete nuclear power islands like those already existing in great number in France.

In each case, of course, there must be a common will to develop successful cooperation. This requires time, tenacity, and an unflagging will to bring things to a successful conclusion, all the more so because each case is a special one. In every instance, the needs to be satisfied are specific to each partner country, as are the goals. One must adapt to these goals and find the solutions that, progressively, step by step, satisfy the partner's legitimate ambitions.

The cooperation plan finally set up can be highly complex and nevertheless yield excellent results. Rather than taking the Daya Bay project as an example, which is familiar to many of you and which is still in the startup stage, I would like to illustrate my point with another example. It is also highly significant and has already reached a state of advancement that makes it possible to foresee the successful outcome with a high degree of confidence.

This example is the KNU 9 & 10 project : twin 900-MWe nuclear power units at Uljin in the Republic of Korea.

The KNU 9 & 10 contract, as its name indicates, did not concern the first nuclear units built in Korea, but came after this country had already launched several nuclear power plant projects and acquired a considerable amount of experience in the field.

The goals of the Republic of Korea were therefore to maximize the participation of its industry in KNU 9 & 10 and to intensify its access to PWR plant technology, to enable further reducing its dependence on foreign vendors for its future nuclear projects.

The Korean nuclear industry was reorganized for this purpose. A major industrial complex called KHIC was set up at Changwon, and constituted the solid foundation on which to build an industrial capability for effective and widescale participation in future nuclear power projects.

For KNU 9 & 10, the goal set for KHIC was to supply, by themselves or through their subcontractors, nearly 30 % of the equipment.

The goal set for the future plant owner, KEPCO, was to be responsible for the construction, erection, and startup activities on the site. For that task, KEPCO had to rely on Korean civil works and equipment erection contractors.

For the foreign vendors, including Framatome, the goals set were to transfer technology to the local manufacturer, KHIC, and to provide technical assistance to KEPCO, KHIC, and to the civil works and erection contractors during the entire project duration.

Which is what we did.

We supplied engineering documentation to the local architect-engineer, KOPEC.

We also provided direct technical assistance, by integrating experience Framatome personnel into KHIC's workshops and into KEPCO's site-management team.

Many KHIC staff members were trained in France, to familiarize them with our fabrication methods, and to take advantage of the consistent set of codes and standard, applied to the French program.

Through these different channels, we were able to share our experience and to solve together the manufacturing and construction problems encountered during the life of the project. We had already run into most of them in France ourselves, so our experience could be of mutual profit.

The project is not yet finished, since the contract was actually implemented in March 1981 and the first concrete poured on 1st February 1983. However, as of now we can already see the progress made and we can be reasonably confident that through close cooperative efforts, the target commissioning dates of March 1988 for KNU 9 and March 1989 for KNU 10 will be met. Furthermore, this project has been carried out on schedule and in a time comparable to that of a French twin-unit plant project.

CONTINUITY OF THE FRENCH NUCLEAR POWER PROGRAM

In any cooperative venture with foreign partners, Framatome offers, with the support of other French organizations all of the experience drawn from the ongoing French nuclear power program.

This experience is continually growing and will continue to do so, because the French nuclear power industry has the rare privilege of being able to rely on a national program that is sure to continue, without interruption, for many tens of years to come. This program is alive and developing, even if its speed must be adjusted to take account of the slowing demand for electricity and the consequences of its own success : much higher energy availability than was forecast 15 years ago for the entirety of France's PWR units.

In the coming years, French nuclear industry will thus continue its efforts, in particular in two main directions :

- Profiting from the experience feedback from the numerous operating units, to maintain and further improve the operation of all the Framatome-built PWRs ;

- Continuing its methodical and prudent approach to step-by-step enhancement of its future models, which is one of the most remarkable aspects of the French nuclear energy story.

Concerning the first of these points, Framatome is making strong advances in the field of nuclear services and associated products. Applying the latest progress in robotics, computerized project management, metallurgy, decontamination, and personnel training, the Maintenance Division has become an innovator and a pacesetter, active in many countries in addition to France.

Concerning the second main axis of effort, careful analysis of the available experimental data will allow our researchers and engineers to further raise plant availability factors, cut down on the number of unscheduled outages, and shorten the duration of maintenance and repair operations.

Other improvements are also being studied, including reducing the cost of plant components, increasing the fuel burnup, lengthening the useful plant operating life, and further enhancing operating flexibility. All of them will go toward reinforcing the competitivity of the "nuclear" kWh.

Another important step forward will be the recycling of plutonium, which requires mastery of the production of mixed-oxide fuel on both the industrial and commercial levels. Beyond that step, research is already in progress on new core design (spectral shift and undermoderated reactors), which will lead to evolution in PWR design. These future advanced light water reactors will respond to new national and international market requirements, such as greater availability and operation flexibility and more efficient use of fissile material.

CONCLUSION

All of the participants in this conference share the conviction that nuclear power remains a key factor in facing up to the world's energy needs of the 21st century.

The year 2000 is now near at hand. The countries of the Pacific basin have understood this. Following their fifth conference at Seoul in 1985, they took the first steps to establishing a cooperation that bears witness at the same time to their confidence in the future and their conviction that such collaboration is essential to successful preparation for the future.

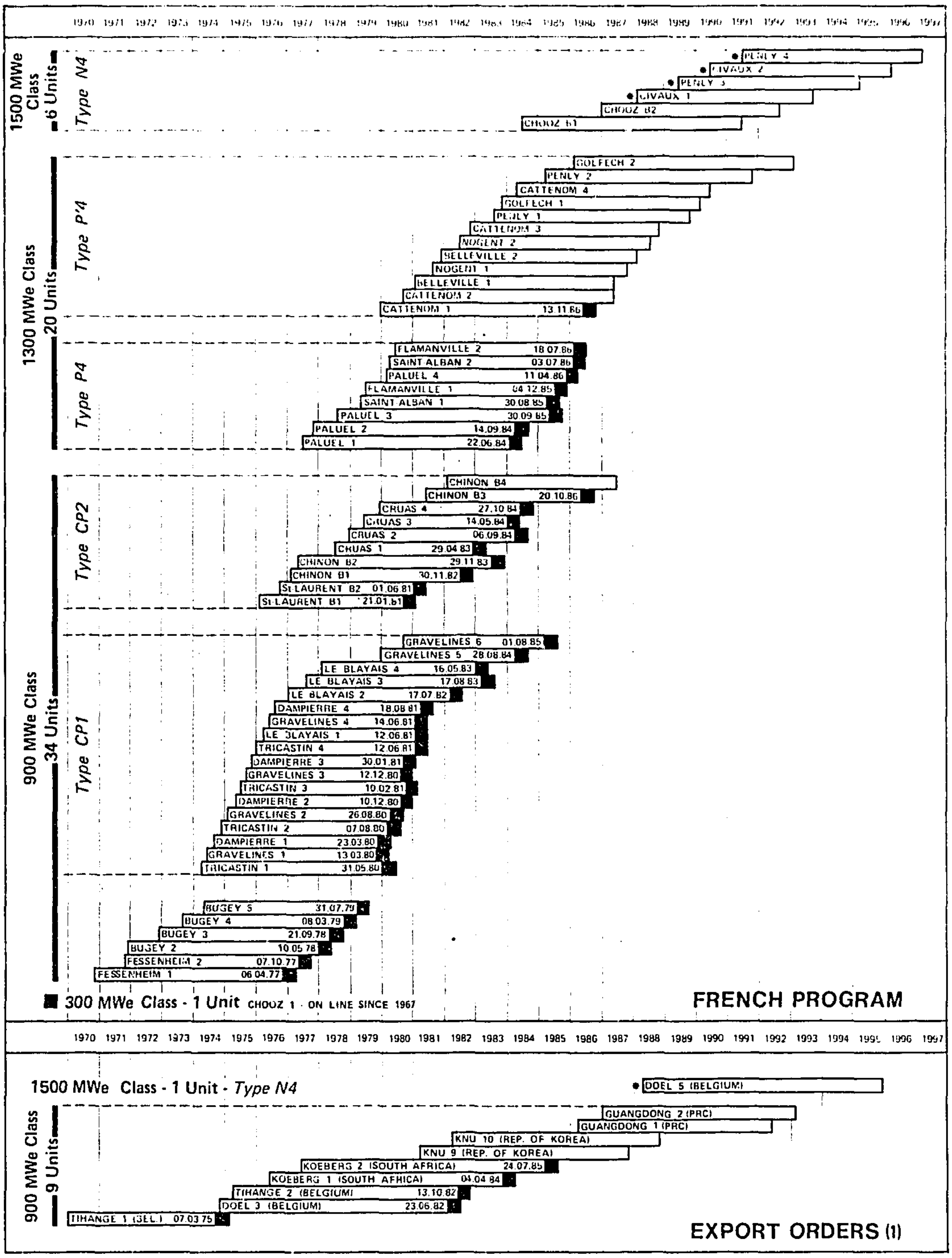
The vitality of the French nuclear power program shows that France has long pursued the same objectives and shares the same convictions. Framatome, for its part, intends to remain among the world leaders in this field, and is actively preparing the future of nuclear power.

At the same time, Framatome is ready to share the fruits of its experience and to devote its resources to a common collaborative effort, whose results can only be beneficial for all concerned.

FRAMATOME

NUCLEAR POWER PLANTS EQUIPPED WITH FRAMATOME PWRs

CONSTRUCTION PROGRAM WITH COUPLING DATES



Total number of units	71
Total number of units coupled to the grid	48
• *Planned units (orders to be confirmed)*	5

For the French Program and for some export orders, FRAMATOME supplies the NSSS.
For KOEBERG 1/2, KNU 9/10 and GUANGDONG 1/2 units, FRAMATOME supplies the complete Nuclear Island.

Order date : start of component manufacturing

Date of coupling : start of electricity generation

(1) Not included : two 900 MWe units in IRAN (contract signed in 1977, terminated in 1979).

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