

Joël Guidez · Gérard Prêle

# Superphenix Technical and Scientific Achievements



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# Superphenix

On the roof!



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# Superphenix

Technical and Scientific  
Achievements



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*This book is dedicated to Mister Georges Vendryes, who spent most of his professional career to the development of fast neutron reactors. He published in 1997 the book “Superphénix, pourquoi ?” (Superphenix, why?) and his own dedication can be taken up again here:*

*“I dedicate this book to the thousands of men and women who fought with enthusiasm, in France and in Europe, so that the fast neutron type of reactors gets developed and so that Superphenix lives.”*

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## Foreword



The conventional wisdom tells “if one wants to know where he is going to, he must look at where he comes from”. Convinced of the merits of this saying, but also of the need to make it live in a person-to-person relationship, I invited Superphenix great engineer, the father of the French sodium reactors, Georges Vendryes, to whom this book is dedicated, to meet, in my office, the person in charge of the studies on this type of reactors, fifty years younger. And I saw, just in front of me, a torch passage with all that entails of human warmth, trust and mutual listening.

In the cold language of modern engineering and project management, this book is an injunction to take full advantage of past experience feedbacks for the development of projects to come. This is the spirit of this book to capitalize the technical and scientific achievements of “Superphenix experience”. In this meaning, it is the following of the volume devoted by Joël Guidez to “Phenix Experience”,<sup>1</sup> which allows us to have an as accurate as possible archiving of the French experience in the field of sodium-cooled fast neutron reactors.

Expertise archiving of course, but the human dimension, the feeling of having participated in a common adventure for the public good, the will to transmit it to the future generations as a precious treasure, all this can be found in the work, of which this book is the outcome.

The objective, obviously not only being the nostalgic contemplation of a time when France was leading the development of civilian nuclear energy, but also, on the opposite, to build a corpus of technical and scientific knowledge required to move on forward in this way.

Since this way remains a promising way for the future. Fission nuclear energy remains, along with hydropower, the best way to produce energy in a central manner with low greenhouse gas contents and thus, in an industrial and urbanized economy, a major asset in the fight against global warming. The two limitations to this technology, the nuclear fuel availability and the

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<sup>1</sup>“Phenix, the experience feedback”, J. Guidez, (2012), ed. EDP sciences.

management of the cycle back end, are greatly reduced in the type of reactors said as “fast neutron”: the controlled plutonium stock management, the control of long-lived waste of the cycle back end, the use of depleted uranium and finally the possibility, if necessary, to continue the minor actinide transmutation. Fashions do change, neutronics remains, and Fermi’s statement in 1945. “The country that will be the first to develop a breeder reactor will draw a decisive commercial benefit for nuclear energy operations” remains fully relevant.

But there is a long way from the “paper reactor” to the industrial product... After Phenix reactor operations, Superphenix was a step towards these ambitious objectives. This is therefore maybe this ambition, which crystallized a strong opposition against the reactor operations. As Georges Vendryes<sup>2</sup> wrote: “It is difficult to construct and few are willing to make this effort. On the opposite, it is easy to destroy, it is affordable to everyone. It is easy to worry, even with no proof, because the anxiety is always present in man heart; but it is not easy to reassure as anxiety feeds itself with irrationality that the best justified arguments are powerless to fight.” More cruelly, Rivarol replied in advance to certain types of detractors “This is a great benefit of having never done anything, but it should not be misused.”

During these eleven years of operations, Superphenix will have been a longer time shutdown, (54 months), because with no authorization to operate, than in operations (53 months). That says as much about our regulatory procedure cumbersomeness as on its technical difficulties. But this reactor, despite this too short life, nevertheless showed that these ambitious objectives were not a dream.

Because of its early stop, a number of intended demonstrations could therefore not be completed, especially on the material or component or fuel life durations. However, a huge harvest of knowledge does exist: first, in terms of design, with the results of tens of test loops and the related development of calculation codes increasingly sharper and validated; in terms of construction, this reactor, built in a European framework, remains the most powerful sodium-cooled fast reactor ever built in the world; it enabled to develop and validate many original solutions. In terms of operations, the contributions were numerous, showing the strengths and weaknesses of the system. Original solutions were also developed in terms of safety and detection, or in terms of in-service inspection. Finally in terms of dismantling, there too, many data are getting accumulated.

The book on Phenix experience feedback was based on data that were available internally at CEA. For Superphenix, which was a project of a very different magnitude, all experience feedbacks were spread between CEA, AREVA and EDF. It was necessary, on the one hand, to access to these data, and on the other hand, to build a synthesis that incorporates each actor’s perception. Joël Guidez was to propose, to recognized experts from the three organizations and to establish a rereading committee. I witness the

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<sup>2</sup>“Superphenix, Pourquoi ?” (*“Superphenix, why?”*), G. Vendryes, (1997), ed. Nucleon.

enthusiasm, with which the project was put to an end, the ardour and the professionalism, with which rereadings were performed. This dynamics fully satisfied me as, if I am convinced that the SFR type of reactors is a real asset for the development of a sustainable nuclear, I am also deeply convinced that such an adventure requires a close and assumed collaboration between the three actors. This is not easy: the immediate economic requirements tend to push away the waste issue and to see only the extra cost in electricity production, and the imperative need for a difficult fuel industrial manufacturing is rapidly forgotten. But the sense of the public good and the long-term reflection require this collaboration. The fact that it occurred so spontaneously in this present book, which describes the reactor construction and operations, is making us feel optimistic about the adventure that lies ahead of us, for the development of a fourth-generation fast reactor and its related cycle.

The result that you have in your hands is a thematic book of a great richness. Theme by theme, it collects and exhibits the gathered knowledge: the reactor construction, the start-up trials, neutronics, the chemistry, the materials, the components, the safety, the environmental results, thermal hydraulics, etc., i.e. altogether twenty-five thematic chapters. It is not trivial to find chapters as technical as “construction review”, “operating results”, “handling”... There are no unimportant questions when such technological jewels are involved. And to go against the Vulgate (*popular opinion*) that claims everywhere to what extent “Superphenix cathedral” was inappropriate, simply it is sufficient to read in detail these chapters of the reactor day-to-day. Certainly Superphenix had technical problems (the storage drum, sensitive to hydrogen embrittlement, being the most famous), but likewise any number one of an industrial series may have. The book concludes with a chapter on the dismantling, where Superphenix also plays a pioneer role.

Chapter 25 “Superphenix Children” is a rebirth, as it should be for the mythical bird. It explains the project design evolutions, during the eleven years of Superphenix operations, intended for reactors that were supposed to extend the experience: the SFR 1500 (said as SPX 2) and the EFR European reactor. These evolutions are obviously valuable for current projects of the future. In the world, today, sodium fast reactors are starting-up: BN 800 in Russia, connected to the grid in December 2015, and PFBR in India. Both projects incorporate the experience feedback available from the first fast reactors, and can then be considered as such, as third-generation reactors. To go far further in terms of safety, that is to say, to develop a fourth-generation prototype fast neutron reactor, requires studies on highly innovative systems for the energy conversion system, for the core neutronics and for all the safety-related provisions linked to the experience feedback from the Fukushima accident and the fourth-generation reactor new safety criteria.

So I think this book will contribute to the required handing over towards these reactors of the future. So thank you to Joël Guidez and to all EDF,

Areva and CEA contributors and experts, who assisted him in this task, particularly to Gerard Prêle, who got passionate by the project. There is nothing that gives as much confidence in the richness of an engineering approach such as a collective work, as to see from the past experience emerge the seeds of an even more efficient future.

This book, I am sure of that, will serve as the reference for all those involved in the design of sodium-cooled fast neutron reactors.

Yves Bréchet  
High Commissioner for Atomic Energy

A handwritten signature in black ink, appearing to read 'Y Bréchet', with a stylized flourish above the name and a period at the end.

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## Preface

When Superphenix reactor was definitely shut down in 1997, the major organizations, which had designed, built and participated to this project, that is to say, CEA, EDF and AREVA, got organized to save the accumulated knowledge, not only during the reactor operations, but also during its design, during its construction, for its fuel manufacturing, and for Superphenix 2 and EFR (European Fast reactor) subsequent projects and studies. All this constituted a dataset not only of exceptional richness, but also of a considerable volume.

For CEA, a database called MADONA, document database developed in a tripartite framework, CEA-AREVA and EDF and since integrated in the SIBIL database, was created, gathering thousands of documents, and the major specialist interview campaigns, which had been performed to save their knowledge. Data concerning fuel manufacturing and Superphenix 2 and EFR project studies were also injected in it.

For AREVA, a large archiving and scanning campaign of all the documents issued on these subjects, including constructive documents, was carried out. This enables, in particular, to find back for each item the data relative to its conception, its design, construction and quality assurance verification modes. This unique industrial experience thus remains available.

For EDF, the NERSA European Group majority actor, which was in charge of the reactor construction, activities and operations, a specific care was provided by EDF SEPTEN for this archiving, which will also bring together the results of research or testing actions carried out in support to the reactor. Furthermore, under the SFR experience feedback works, performed by SEPTEN in 2007 and 2008, twenty-seven summary notes were also written on thematic subjects, which reduced, during the writing of this book, the number of times when old files had to be “dug out”.

Writing this book therefore gives as main objective to allow a reader to have a synthetic approach of this vast whole. This approach should enable to have an Ariadne’s thread for the people wanting to enter inside this labyrinth, and wishing to have an experience feedback overview before going on for further enhancements.

This goal induced another one: the search for a “scientific truth”. On such volumes of documents, and such durations, small differences may sometimes appear in the various available documents. We tried, as much as possible, to

understand them by interviewing the involved experts and to come to a consensus on the final conclusions and values proposed here.

Finally, what has not been said on this reactor to justify its early stop: too expensive, too big, dangerous, always broken down, useless, etc? Far from entering this controversy, this book simply gives the exact values: on the costs in Chaps. 2 and 25, on safety in Chap. 5 and many other chapters, on the shutdowns and the operating issues in Chap. 4 and many others. So, let us the reader read these chapters and build up his own opinion.

Have a Good reading

Gif-sur-Yvette, France

Joël Guidez

A handwritten signature in black ink, appearing to read 'Joël Guidez', with a stylized flourish extending to the right.

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- All my thanks to Mister Yves Bréchet, High Commissioner, who initiated this project and continuously supported me in my approach. Without his support, this project would never have been possible and be completed.
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- Jean-François Sauvage (EDF), also author of "Phenix. 35 years of history: the heart of a reactor" brought his high knowledge on Superphenix, for which he has worked for a long time. His numerous advices were invaluable.
- Also thank you to Rémy Dupraz (AREVA) for his advices and for the substantial bibliographies and iconographies that he provided.
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Generally speaking, this book on Superphenix technical and scientific achievements owes much to all those who—for years—have contributed to the development of the type of fast reactors and drafted documents and syntheses, which were absolutely essential to me. A particular mention for Gérard Prêle and Jean-François Sauvage syntheses, performed as part of the experience feedback analysis works achieved by EDF SEPTEN in 2007 and 2008, which were quite useful in their respective fields. It may be noted the one on the reactor construction by Claude Acket (AREVA), the one by Henry Guillet (CEA) on fuel manufacturing, the one by Sylvain Janski (EDF) on neutronics, the thermohydraulics tuition by Jan-Patrice Simoneau

(EDF) for the operators' safety training course, Gilles Rodriguez (CEA) synthesis on in-gas handling ... and so many others, with my apologies to all those not mentioned.

I will conclude by thanking the former Head of Plant, Pierre Schmitt, who provided numerous photographs, which are those of the EDF Creys-Malville database. I thank Creys-Malville site, in particular its Director Damien Bilbault, for the authorization that we were given to publish the photos included in this book. I also thank our EDF drawers: Jean Luc Chauveau (said as Jiel) and Nicolas Waeckel, who kindly allowed us to use their talented cartoons.

Joël Guidez

A handwritten signature in black ink, appearing to read 'Joël Guidez', with a stylized flourish extending to the right.

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## About the Book

Superphenix has a unique place in the French electricity-generating nuclear fleet. It remains today the most powerful sodium-cooled fast reactor ever built and operated in the world. Built in seven years, between 1977 and 1984, it will reach its rated power at the end of 1986. Crystallizing a significant political opposition, it will be prematurely stopped in 1997. The experience gained during the design studies, the manufacturing phases, the 11 years of operations and the beginning of dismantling represent however a huge data volume, stored by the different actors. This book makes an attempt to synthesize, for the fourth-generation future reactors, the scientific and technical achievements gained, thanks to this reactor.

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