



THE RENAISSANCE OF SODIUM FAST REACTORS

STATUS AND CONTRIBUTION OF PHENIX

J. Guidez

Director of Phenix plant



The sodium fast reactors in operation in the world in 2007



- **18 SFR were or are operated in a number of countries**
- **In 2007, six reactors remain on operation in the world.**
- **Three SFR are under construction.**
- **In 2007 the cumulated number of years of operation of these 18 reactors is of 379 years.**



Fast reactor operationnal data



FAST REACTORS OPERATIONAL DATA 2007				
Reactor (country)	Thermal Power (MW)	First criticality	Final shut-down	Operational period (years)
EBR-I (USA)	1.4	1951	1957	6
BR-5/BR-10 (Russia)	8	1958	2002	44
DFR (UK)	60	1959	1977	18
EBR-II (USA)	62.5	1961	1991	30
EFFBR (USA)	200	1963	1972	9
Rapsodie (France)	40	1967	1983	16
BOR-60 (Russia)	55	1968		39
SEFOR (USA)	20	1969	1972	3
BN-350 (Kazakhstan)	750	1972	1999	27
Phenix (France)	563	1973		34
PFR (UK)	650	1974	1994	20
JOYO (Japan)	50-75/100	1977		30
KNK-II (Germany)	58	1977	1991	14
FFTF (USA)	400	1980	1993	13
BN-600 (Russia)	1470	1980		24
SuperPhenix (France)	3000	1985	1997	12
FBTR (India)	40	1985		22
MONJU (Japan)	714	1994		13
BN-800 (Russia)	2000	Under construction		
CEFR (China)	65	Under construction		
PFBR (India)	1250	Under construction		
Total All Fast Reactors				379

Total per country (years)	
Russia	110
USA	61
France	62
UK	38
Japan	43
Kazakhstan	27
India	22
Germany	14

Generation IV Forum



- **The generation IV Forum has established a list of six types of nuclear systems for the future:**
 - **VHTR.**
 - **Gas cooled fast reactor.**
 - **Sodium cooled fast reactor.**
 - **Lead-cooled fast reactor.**
 - **Molten salt reactor.**
 - **Super critical water cooled reactor.**
- **What is the situation, in 2007, in the main « nuclear countries » with regard to these six types of reactor ?**



KOREA



- **Announcement of the choice of sodium fast reactor as concept for the future.**
- **Only design studies today, no prototype construction plan.**



CHINA



- **Activities in the field of HTR, with a prototype reactor on operation.**
- **A 75 MWth sodium cooled fast reactor (CEFR) is under construction, scheduled for criticality in 2010.**



INDIA



- **The sodium fast reactor FBTR is on operation since 1985 .**
- **A 1200 MWth reactor (PBFR) is under construction for a divergence in 2010.**
- **It is the first reactor in a series of three reactors.**



RUSSIA



- **Two SFR are on operation: BOR 60 (research reactor) and BN600(600MWe).**
- **The reactor BN800 is under construction (new budgeting and restart of construction in 2006).**



JAPAN



- **The research reactor JOYO is on operation.**
- **MONJU (250MWe) is in a recommissioning phase after completion of modification work in 2006.**
- **Japan is the leading country in GENIV Forum for SFR.**



JOYO



MONJU



USA



- **The GNEP project includes an actinide burning fast reactor.**
- **A call for interest was made in 2006 for a sodium cooled fast reactor.**



France : a prototype of reactor GEN IV in 2020



- **Announcement of the French president in January 2006 : « a prototype of reactor GEN IV should be in operation at the end of 2020 ».**
- **In June 2006, law on nuclear waste, specifying that a prototype, able to burn actinides, should be operational by the end of 2020.**
- **December 2006, « conseil à l'énergie nucléaire » and confirmation of this SFR prototype for 2020 Studies will continue on the gas fast reactor, more in the frame of an European project for the long term.**



Conclusion for GENIV Forum



- **The SFR has the significant advantage of 379 years of operating experience on 18 reactors.**
- **SFR projects in Korea and USA, and reactor on operation or under construction in China, France, Russia, India and Japan.**



Sodium fast reactor and sustainable development (1)



- **The SFR are able to burn all the uranium.**
- **The industrial demonstration has been made in Phenix during the years 1980, when 4,5 core (about 25 Tons of fuel) were reprocessed and when Phenix fuel elements were fabricated with reprocessed plutonium and burnt again (3 times).**
- **With the depleted uranium available in France (more than 100 000 tons), and with a SFR fleet, 5000 years of total French electricity production could be produced !**



Sodium fast reactors and sustainable development (2)



- **After separation of actinides, the ultimate nuclear waste obtained after reprocessing, would have a shorter radioactive life (about 300 years)**
- **These actinides can be burnt only in fast reactors, for neutronic reasons.**
- **They can be burnt in homogeneous way (small quantities in the fuel), or in heterogeneous way (almost pure actinides in dedicated targets)**
- **A test program has been developed at Phenix for this matter.**



Phenix operation



- **Phenix has restarted in 2003 after safety upgrading**
- **The availability factor has been good: 78 % in 2004, 85% in 2005 and 78% in 2006.**
- **Recently, in January 2007, the Phenix historical record of operation without shutdown (99 days) was broken.**
- **Significant Irradiation test program in the reactor, including a lot of international experiments involving Europe, Japan and USA**



Transmutation research in Phenix



- **Several parameters can be changed:**
 - ✓ **choice of actinide: Neptunium, Americium, or Curium,**
 - ✓ **homogeneous or heterogeneous mode,**
 - ✓ **percentage of actinides in the fuel,**
 - ✓ **type of fuel: oxides, metal, nitrides or carbides.**

- **This explains that about twenty experiments today are being irradiated in the Phenix core.**



An example of experiment: ECRIX H



- **ECRIX H is an experiment of americium burning in heterogeneous mode using a dedicated device.**
- **After two cycles, this experiment loaded in the Phenix core in 2003 was discharged in February 2006.**
- **Destructive examinations are not yet completed, but about 95 % of americium should have disappeared.**



Experiments to be loaded at the next reactor shutdown in April 2007



- **Seven new experiments should be loaded during the next shutdown in April 2007, with a number of them in the frame of international cooperation (USA, Europe and Japan.)**
- **FUTURIX MI (material testing at high temperature), CAMIX and COCHIX (New heterogeneous transmutation targets), FUTURIX METAL (transmutation targets in metal fuel), FUTURIX CERCER and CERMET (transmutation targets in oxide fuel) and FUTURIX CONCEPT (test of various new fuels like carbides for Gas Fast Reactors).**



CONCLUSION



- **The fast breeder reactors are totally in the frame of sustainable development, for preserving natural resources (breeding) and improving waste management (transmutation).**
- **Sodium Fast Reactors are on operation or under construction or projects in many countries, with a total operating experience of 379 years.**
- **The Phenix reactor is operating well, since its restart in 2003, and after demonstration of the breeding possibilities in the 1980's, it is demonstrating today the transmutation capabilities of these reactors.**

