DOWNLOAD PDF FAST BREEDER REACTORS: EXPERIENCE AND TRENDS

Chapter 1 : Global Nuclear Decommissioning Market - Size, Forecasts (â€“)

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India nearing completion of MW commercial fast breeder reactor India nearing completion of MW commercial fast breeder reactor brian wang July 3, India plans to commission its first fast breeder reactor FBR by the end of this year at Kalpakkam in the southern state of Tamil Nadu. India would be the second country worldwide to have a commercial reactor currently produce power through a fast-breeder reactor. Countries such as the US, France, and Japan have also experimented with fast breeder technology programmes. France had a commercial fast breeder Superphenix reactor from to The first stage of this employs PHWRs fuelled by natural uranium, and light water reactors, to produce plutonium. Stage two uses fast neutron reactors burning the plutonium to breed U from thorium. The blanket around the core will have uranium as well as thorium, so that further plutonium ideally high-fissile Pu is produced as well as the U Then in stage three, advanced heavy water reactors burning the U and this plutonium as driver fuels, but utilising thorium as their main fuel, and getting about two thirds of their power from the thorium. A MWe prototype fast breeder reactor PFBR is under construction at Kalpakkam and was expected to be operating late in , fueled with uranium-plutonium oxide. It is now exptected to begin operation in It will have a blanket with thorium and uranium to breed fissile U and plutonium respectively. Initial FBRs will have mixed oxide fuel or carbide fuel but these will be followed by metallic fueled ones to enable shorter doubling time. Four more such fast reactors have been announced for construction by Initial Indian FBRs will be have mixed oxide fuel but these will be followed by metallic-fuelled ones to enable shorter doubling time. It envisages metal fuels after In it will change over fully to pelletised MOX fuel when a new fuel plant is completed. It does not have a breeding blanket, though a version designed for Sanming in China allows for up to DU fuel elements in a blanket. Service life is 40 years. Net thermal efficiency is It is capable of burning up to 3 tonnes of plutonium per year from dismantled weapons 1. An important feature of BN closed-loop fuel cycle is that actinides both plutonium and minor actinides produced in the reactor are consumed in the same reactor. The reactor fuel cycle in equilibrium accommodates about 5 t plutonium including 3 t in the core and 2 t in the external fuel cycle , and about kg minor actinides. It is assumed that the reactor core would be recycled 20 times in 40 years of service life, based on equivalent days of a fuel campaign. The main purpose of the BN is to provide operating experience and technological solutions, especially regarding the fuel, that will be applied to the BN In two BN reactors were sold to China. Construction at Sanming is delayed from intended start in and may happen after It will have active and passive shutdown systems and passive decay heat removal. MOX is seen only as an interim fuel, the target arrangement is metal fuel in closed cycle. See fuller description below.

Chapter 2 : The Breeder Reactor

Fast breeder reactors: experience and trends: proceedings of an International Symposium on Fast Breeder Reactors, Experience and Future Trends, organized by the International Atomic Energy Agency and held in Lyons,

In broad terms, spent nuclear fuel has two main components. The first consists of fission products , the leftover fragments of fuel atoms after they have been split to release energy. Fission products come in dozens of elements and hundreds of isotopes, all of them lighter than uranium. The second main component of spent fuel is transuranics atoms heavier than uranium , which are generated from uranium or heavier atoms in the fuel when they absorb neutrons but do not undergo fission. All transuranic isotopes fall within the actinide series on the periodic table , and so they are frequently referred to as the actinides. The physical behavior of the fission products is markedly different from that of the transuranics. In particular, fission products do not themselves undergo fission, and therefore cannot be used for nuclear weapons. Furthermore, only seven long-lived fission product isotopes have half-lives longer than a hundred years, which makes their geological storage or disposal less problematic than for transuranic materials. After " spent nuclear fuel " is removed from a light water reactor, it undergoes a complex decay profile as each nuclide decays at a different rate. Due to a physical oddity referenced below, there is a large gap in the decay half-lives of fission products compared to transuranic isotopes. If the transuranics are left in the spent fuel, after 1, to , years, the slow decay of these transuranics would generate most of the radioactivity in that spent fuel. Thus, removing the transuranics from the waste eliminates much of the long-term radioactivity of spent nuclear fuel. Because commercial reactors were never designed as breeders, they do not convert enough uranium into plutonium to replace the uranium consumed. Nonetheless, at least one-third of the power produced by commercial nuclear reactors comes from fission of plutonium generated within the fuel. All proposed nuclear reactors except specially designed and operated actinide burners [16] experience some degree of conversion. As long as there is any amount of a fertile material within the neutron flux of the reactor, some new fissile material is always created. The ratio of new fissile material in spent fuel to fissile material consumed from the fresh fuel is known as the "conversion ratio" or "breeding ratio" of a reactor. For example, commonly used light water reactors have a conversion ratio of approximately 0. Pressurized heavy water reactors PHWR running on natural uranium have a conversion ratio of 0. This was considered an important measure of breeder performance in early years, when uranium was thought to be scarce. However, since uranium is more abundant than thought, and given the amount of plutonium available in spent reactor fuel, doubling time has become a less-important metric in modern breeder-reactor design. Burnup is an important factor in determining the types and abundances of isotopes produced by a fission reactor. Breeder reactors, by design, have extremely high burnup compared to a conventional reactor, as breeder reactors produce much more of their waste in the form of fission products, while most or all of the actinides are meant to be fissioned and destroyed. Starting at uranium, isotopes of plutonium, americium, and curium are all produced. In a fast neutron-breeder reactor, all these isotopes may be burned as fuel. Many types of breeder reactor are possible: In principle, almost any reactor design could be tweaked to become a breeder. An example of this process is the evolution of the Light Water Reactor, a very heavily moderated thermal design, into the Super Fast Reactor [26] concept, using light water in an extremely low-density supercritical form to increase the neutron economy high enough to allow breeding. Aside from water cooled, there are many other types of breeder reactor currently envisioned as possible. These include molten-salt cooled , gas cooled , and liquid-metal cooled designs in many variations. Almost any of these basic design types may be fueled by uranium, plutonium, many minor actinides, or thorium, and they may be designed for many different goals, such as creating more fissile fuel, long-term steady-state operation, or active burning of nuclear wastes. Extant reactor designs are sometimes divided into two broad categories based upon their neutron spectrum, which generally separates those designed to use primarily uranium and transuranics from those designed to use thorium and avoid transuranics. Fast breeder reactor FBR which use fast i. The fast spectrum is flexible enough that it can also breed fissile uranium from thorium, if desired. Thermal breeder reactor which use thermal-spectrum i. Due to the behavior of the various nuclear fuels, a thermal breeder is thought commercially feasible only with thorium fuel, which avoids the buildup of the heavier transuranics. Reprocessing[edit] Fission of the nuclear fuel in any reactor produces neutron-absorbing fission products. Because of this unavoidable physical process, it is necessary to reprocess the fertile material from a breeder reactor to remove those neutron poisons. This step is required to fully utilize the ability to breed as much or more fuel than is consumed. All reprocessing can present a proliferation concern, since it extracts weapons-usable material from spent fuel. Early proposals for the breeder-reactor fuel cycle posed an even greater proliferation concern because they would use PUREX to separate plutonium in a highly attractive isotopic form for use in nuclear weapons. For instance, the non-water-based pyrometallurgical electrowinning process, when used to reprocess fuel from an integral fast reactor , leaves large amounts of radioactive actinides in the reactor fuel. All these systems have modestly better proliferation resistance than PUREX, though their adoption rate is low. If the protactinium remains in the reactor, small amounts of uranium are also produced, which has the strong gamma emitter thallium in its decay chain. Similar to uranium-fueled designs, the longer the fuel and fertile material remain in the reactor, the more of these undesirable elements build up. In the envisioned commercial thorium reactors, high levels of uranium would be allowed to accumulate, leading to extremely high gamma-radiation doses from any uranium derived from thorium. These gamma rays complicate the safe handling of a weapon and the design of its electronics; this explains why uranium has never been pursued for weapons beyond proof-of-concept demonstrations.

Chapter 3 : Fast Neutron Reactors | FBR - World Nuclear Association

Fast breeder reactors: experience and trends: proceedings of an international symposium on fast breeder reactors: experience and future trends.

The Breeder Reactor Conventional nuclear reactors use uranium as their fuel. Most uranium occurs as the isotope uranium However, if uranium could be used as a nuclear fuel, there would be sufficient uranium to run nuclear reactors for hundreds of years. The Breeder Reactor was developed to use uranium A reactor is built with a core of fissionable plutonium, Pu The plutonium core is surrounded by a layer of uranium As the plutonium undergoes spontaneous fission, it releases neutrons. These neutrons convert uranium to plutonium In other words, this reactor breeds fuel Pu as it operates. After all the uranium has been changed to plutonium, the reactor is refueled. However, there are some major problems with the breeder reactor. To begin with, plutonium is extremely toxic. If an individual inhales a small amount, he or she will contract lung cancer. Also, the half-life of the material is extremely long, about 24, years. This could create an almost impossible disposal problem if large amounts of this material are generated. Instead, liquid sodium must be used. In the event of an accident a catastrophe could develop because sodium reacts violently with water and air. Although the breeder reactor could solve the uranium fuel problem, there are still a number of other problems that will have to be worked out. The superior neutron economy of a fast neutron reactor makes it possible to build a reactor that, after its initial fuel charge of plutonium, requires only natural or even depleted uranium feedstock as input to its fuel cycle. This fuel cycle has been termed the plutonium economy. The Thermal Breeder Reactor. The excellent neutron capture characteristics of fissile Uranium make it possible to build a heavy water moderated reactor that, after its initial fuel charge of enriched uranium, plutonium or MOX, requires only thorium as input to its fuel cycle. Thorium produces Uranium after neutron capture and beta decay. In addition to this, there is some interest in so-called "reduced moderation reactors" which are derived from conventional reactors and use conventional fuels and coolants, but are designed to be reasonably efficient as breeders. Such designs typically achieve breeding ratios of 0. A Breeder consumes fissile and fertile material at the same time as it creates new fissile material. Production of fissile material in a reactor occurs by neutron irradiation of fertile material, particularly Uranium and Thorium In a breeder reactor, these materials are deliberately provided, either in the fuel or in a Breeder Blanket surrounding the core, or most commonly in both. Production of fissile material takes place to some extent in the fuel of all current commercial nuclear power reactors. Towards the end of its life, a uranium PWR fuel element is producing more power from the fissioning of plutonium than from the remaining uranium Historically, in order to be called a breeder, a reactor must be specifically designed to create more fissile material than it consumes. Under appropriate operating conditions, the neutrons given off by fission reactions can "breed" more fuel from otherwise non-fissionable isotopes. The most common breeding reaction is that of plutonium from non-fissionable uranium The term "fast breeder" refers to the types of configurations which can actually produce more fissionable fuel than they use, such as the LMFBR. This scenario is possible because the non-fissionable uranium is times more abundant than the fissionable U and can be efficiently converted into Pu by the neutrons from a fission chain reaction. France has made the largest implementation of breeder reactors with its large Super-Phenix reactor and an intermediate scale reactor BN on the Caspian Sea for electric power and desalinization. As of , the technology is not economically competitive to thermal reactor technology; but Japan, China, Korea, and Russia are all committing substantial research funds to further development based on existing LMFBR designs, anticipating that rising uranium prices will change this in the long term. As well as their thermal breeder program, India is also developing FBR technology, using both uranium and thorium feedstocks. Breeding Plutonium Fissionable plutonium can be produced from non-fissionable uranium by the reaction illustrated. The bombardment of uranium with neutrons triggers two successive beta decays with the production of plutonium. The amount of plutonium produced depends on the breeding ratio. Plutonium

Breeding Ratio In the breeding of plutonium fuel in breeder reactors, an important concept is the "Breeding Ratio", the amount of fissile plutonium produced compared to the amount of fissionable fuel like U used to produced it. This is based on 2. The time required for a breeder reactor to produce enough material to fuel a second reactor is called its doubling time, and present design plans target about ten years as a doubling time. A reactor could use the heat of the reaction to produce energy for 10 years, and at the end of that time have enough fuel to fuel another reactor for 10 years. Historically, attention has focused upon reactors with high breeding ratios, so that they produce more fissile material than they consume. Such designs range from a breeding ratio of 1. Theoretical models of gas-cooled breeders show breeding ratios of up to 1. In normal operation, most large commercial reactors experience some degree of fuel breeding. It is customary to refer only to machines optimized for this trait as true breeders, but industry trends are pushing breeding ratios steadily higher, thus blurring the distinction. Liquid-Metal, Fast-Breeder Reactor The plutonium breeder reactor is commonly called a fast breeder reactor, and the cooling and heat transfer is done by a liquid metal. The metals which can accomplish this are sodium and lithium, with sodium being the most abundant and most commonly used. The reactor fuel is surrounded by a "blanket" of non-fissionable U No moderator is used in the breeder reactor since fast neutrons are more efficient in transmuting U to Pu At this concentration of U, the cross-section for fission with fast neutrons is sufficient to sustain the chain-reaction. Using water as coolant would slow down the neutrons, but the use of liquid sodium avoids that moderation and provides a very efficient heat transfer medium. That immediately raised the question of safety since sodium metal is an extremely reactive chemical and burns on contact with air or water sometimes explosively on contact with water. It is true that the liquid sodium must be protected from contact with air or water at all times, kept in a sealed system. However, it has been found that the safety issues are not significantly greater than those with high-pressure water and steam in the light-water reactors. That brackets the range of operating temperatures for the reactor so that it does not need to be pressurized as does a water-steam coolant system. It has a large specific heat so that it is an efficient heat-transfer fluid. It was put into service in France in Surrounding the core is a region called the breeder blanket consisting of tubes filled only with uranium oxide. The entire assembly is about 3x5 meters and is supported in a reactor vessel in molten sodium. Enough excess fuel is produced over about 20 years to fuel another such reactor. Breeding Versus Burnup All commercial Light Water Reactors breed fuel, they just have breeding ratios that are very low compared to machines traditionally considered "breeders. As burnup increases, a higher percentage of the total power produced in a reactor is due to the fuel bred inside the reactor. This corresponds to a breeding ratio for these reactors of about 0. Namely, about half of the fissile fuel in these reactors is bred there. This is of interest largely due to the fact that next-generation reactors such as the European Pressurized Reactor, AP and Pebble Bed Reactor are designed to achieve very high burnup. This directly translates to higher breeding ratios. Current commercial power reactors have achieved breeding ratios of roughly 0. Breeding of fissile fuel is a common feature in reactors, but in commercial reactors not optimized for this feature it is referred to as "Enhanced Burnup". Up to a third of all electricity produced in our current reactor fleet comes from bred fuel, and the industry is working steadily to increase that percentage as time goes on. Reprocessing Use of a breeder reactor assumes nuclear reprocessing of the breeder blanket at least, without which the concept is meaningless. In practice, all proposed breeder reactor programs involve reprocessing of the fuel elements as well. This is important due to nuclear weapons proliferation concerns, as any nation conducting reprocessing using the traditional aqueous-based PUREX family of reprocessing techniques could potentially divert plutonium towards weapons building. In practice, commercial plutonium from reactors with significant burnup would require sophisticated weapon designs, but the possibility must be considered. To address this concern, modified aqueous reprocessing systems are proposed which add extra reagents which force minor actinide "impurities" such as curium and neptunium to commingle with the plutonium. Such impurities matter little in a fast spectrum reactor, but make weaponizing the plutonium extraordinarily difficult, such that even very sophisticated weapon designs are likely to fail to fire properly. Even more comprehensive are such systems as the IFR pyroprocessing system, which uses pools of molten cadmium and electro-refiners to reprocess metallic fuel directly on-site at the reactor. Such systems not only commingle all the minor actinides with both uranium and plutonium, they are compact and self-contained, so that no plutonium-containing material ever needs to be transported away from the site of the breeder reactor. Breeder reactors incorporating such technology would most likely be designed with breeding ratios very close to 1. A block of natural uranium metal about the size of a milk crate delivered once per month would be all the fuel such a 1 gigawatt reactor would need. Such self-contained breeders are currently envisioned as the final self-contained and self-supporting ultimate goal of nuclear reactor designers. As of only India is developing this technology. Their stated intention is to use both fast and thermal breeder reactors to supply both their own fuel and a surplus for non-breeding thermal power reactors. Total worldwide resources of thorium are roughly three times those of uranium, so in the extreme long term this technology may become of more general interest. The Liquid Fluoride Reactor was also developed as a thermal breeder. Liquid-fluoride reactors have many attractive features, such as deep inherent safety due to their strong negative temperature coefficient of reactivity and their ability to drain their liquid fuel into a passively-cooled and non-critical configuration and ease of operation. They are particularly attractive as thermal breeders because they can isolate protactinium the intermediate breeding product of thorium from neutron flux and allow it to decay to uranium, which can then be returned to the reactor. Typical solid-fueled reactors are not capable of accomplishing this step and thus U is formed upon further neutron irradiation.

Chapter 4 : Global Nuclear Decommissioning Market | Growth, Trends, and Forecast (-)

Fast breeder reactors experience and trends: proceedings of an international symposium on fast breeder reactors: experience and future trends.

Historically, attention has focused upon reactors with low breeding ratios at or slightly above a breakeven value of 1. Such designs range from a breeding ratio of 1. It is customary to refer only to machines optimized for this trait as true breeders, but industry trends are pushing breeding ratios steadily higher, thus blurring the distinction. As burnup increases, a higher percentage of the total power produced in a reactor is due to the fuel bred inside the reactor. This corresponds to a breeding ratio for these reactors of about 0. That is to say, about half of the fissile fuel in these reactors is bred there. MOX fuel has a smaller breeding effect than U fuel and is thus more challenging and slightly less economic to use due to a quicker drop off in reactivity through cycle life. This directly translates to higher breeding ratios. Current commercial power reactors have achieved breeding ratios of roughly 0. Breeding of fissile fuel is a common feature in reactors, but in commercial reactors not optimized for this feature it is referred to as "enhanced burnup". Up to a third of all electricity produced in the current US reactor fleet comes from bred fuel, and the industry is working steadily to increase that percentage as time goes on. Types of breeder reactors Two types of traditional breeder reactor have been proposed: In addition to this, there is some interest in so-called "reduced moderation reactors", [8] which are derived from conventional reactors and use conventional fuels and coolants, but are designed to be reasonably efficient as breeders. Such designs typically achieve breeding ratios of 0. In practice, all proposed breeder reactor programs involve reprocessing of the fuel elements as well. In practice, commercial plutonium from reactors with significant burnup would require sophisticated weapon designs, but the possibility must be considered. Such impurities matter little in a fast spectrum reactor, but make weaponizing the plutonium extraordinarily difficult, such that even very sophisticated weapon designs are likely to fail to fire properly. Breeder reactors incorporating such technology would most likely be designed with breeding ratios very close to 1. The Fast Breeder Reactor Main article: Liquid-fluoride reactors have many attractive features, such as deep inherent safety due to their strong negative temperature coefficient of reactivity and their ability to drain their liquid fuel into a passively-cooled and non-critical configuration and ease of operation. Their stated intention is to use both fast and thermal breeder reactors to supply both their own fuel and a surplus for non-breeding thermal power reactors. Total worldwide resources of thorium are roughly three times those of uranium, so in the extreme long term this technology may become of more general interest. Traveling Wave Reactor Main article: If it were to be built, it would be fueled by natural uranium, depleted uranium or thorium and would be able to operate for many years without needing any refueling.

Chapter 5 : Breeder Reactors

In October METI's Conference on Fast Reactor Development agreed that it would be technologically possible to develop a demonstration reactor using the experience obtained from the prototype fast breeder reactor (FBR) Monju and the experimental reactor Joyo, owned by the Japan Atomic Energy Agency (JAEA).

Chapter 6 : India nearing completion of MW commercial fast breeder reactor - blog.quintoapp.com

Fast Breeder Reactors covers the proceedings of the London Conference on Fast Breeder Reactors, organized by the British Nuclear Energy Society. This conference highlights the technical and commercial aspects of nuclear power.

Chapter 7 : Breeder reactor - Wikipedia

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By using sodium as coolant special boundary conditions result for the inservice inspection (ISI) of fast breeder reactors. For that reason in general it is not successful applying the methods and equipment proved for the of light water reactors.

Chapter 8 : Prototype Fast Breeder Reactor - Wikipedia

based on experience in the design and operation of pressure-vessel reactors under pressure in water-moderated, water-cooled power reactors (VV~Rs) and fast reactors. In a steam-water-.