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Chapter 1 : Nuclear reactor - Three Mile Island and Chernobyl | calendrierdelascience.com

Recognizing the roles of heat and mass transfer in all aspects of fission-product behavior in sever reactor accidents, the Executive Committee of the International Centre for Heat and Mass Transfer.

Through the failure of an important valve to operate correctly, cooling water to the core was lost, parts of the core were melted and the rest of it destroyed, and a large quantity of fission products was released from the primary reactor system to the interior of the containment structure. The equipment failure was exacerbated by reactor operator error, as the emergency core cooling system was deactivated by operator action because of a misinterpretation of the type of accident that was occurring. Fortunately, the containment vessel of the reactor building fulfilled its function, and only a small amount of radioactivity was released, demonstrating the wisdom of incorporating this structure into a rigorous design. All the same, a severe accident had occurred. Recommendations differed among them, but a common thread was that the human element was a much more important factor and higher risk to the safe operations of a nuclear power plant than had been recognized. The human element pertained not only to the operating staff but also to the management of nuclear plants and even the NRC itself. As a result, following the accident many changes in operator training and in technical and inspectorate staffing were implemented , just as a number of hardware enhancements were introduced. It is generally believed that these changes have been effective in reducing the likelihood of the occurrence of accidents as severe as that at Three Mile Island. As a side issue to this, however, the operating costs of nuclear power plants have escalated sharply as more and more highly trained people have been added to the operating staffs. The significance of the human element, particularly as it relates to plant management and rigorous high-level regulatory decision making , was borne out again by the Chernobyl disaster of One of the four reactors in a nuclear power station approximately km 60 miles north of Kiev , Ukraine then part of the Soviet Union , exploded and caught fire as the result of an ill-conceived experiment a test to quantify how long the steam turbine s would run while coasting to a stop if the reactor was abruptly shut down. Before the event was brought under control, an estimated 25 percent of the radioactive contents of the reactor had been released in a high cloud plume. Approximately, people had to be evacuated, and a large area surrounding the plant received fallout so great that it could not be farmed or pastured as a result of this accident. Significant levels of radiation were detected as far north as Scandinavia and as far west as Switzerland. Approximately 50 emergency workers had died of acute radiation sickness shortly after the accident, and 9 children had died from thyroid cancer because of radiation exposure. From among the , emergency workers who were present at the site in the first year following the accident, the people who were evacuated, and the , residents of the most heavily contaminated areas, an additional 3, people were likely to die from cancer during a prolonged period after the accident. Investigation of the Chernobyl accident placed the largest blame, as with the Three Mile Island mishap, on poor management both at the plant and within the government bureaucracy. Because these accidents primarily resulted from human failings rather than from some intrinsic factor , most experts have continued to believe that nuclear energy can be a safe source of power. There is, however, a condition on the conclusion that nuclear power is by and large a safe form of power. The facilities for generating this power must be designed, built, and operated to high standards by knowledgeable, well-trained professionals, and a regulatory mechanism capable of enforcing these standards must be in place. Mitigating measures Systems and structures Mitigating measures, also referred to as safety systems, are systems and structures that prevent accidents from proceeding to a catastrophic outcome in the event they do occur. Two of the principal mitigating measures, described in the section Reactor design and components , are 1 the safety rod systems that quickly put the reactor into a subcritical state and prevent a supercritical accident and 2 the containment structure that prevents radioactive materials from being released into the atmosphere. Other significant mitigating measures include the emergency core-cooling system, whose purpose is to provide sufficient cooling of the core and fuel region within the vessel upon a loss of reactor coolant, and the emergency power

system, which is designed to supply electrical power to support systems in the event that the normal supply is disrupted. Emergency power systems are necessary so that detectors, circulating pumps, valves, and other critical components continue to operate as necessary to remove decay heat. An extreme mitigating measure is the evacuation of personnel who might otherwise be heavily exposed in a reactor installation. According to PRA studies, three categories of events are primarily responsible for the risks associated with LWRsâ€”namely, station blackout, so-called transient without scram, and loss of cooling. In station blackout, a failure in the power line to which the station is connected is postulated. The proposed emergency defense is a secondary electrical system, typically a combination of diesel generators big enough to drive the pumps and a battery supply sufficient to run the instruments. In transient without scram, the assumed event is an insertion of positive reactivityâ€”for example, through an undesired withdrawal of the shim rods. The protective safety system response in this case is the rapid and automatic insertion of the safety rods. In loss of coolant, the event is assumed to be caused by a mechanical failure of the normal cooling system such that a certain amount of the coolant is lost. The emergency response is activation of an emergency core-cooling system. In all such measures, proper operator action and proper functioning of the appropriate backup system are paramount aspects of emergency response. Other reactor designs pose different types of risk. For example, neither the pool-type liquid-metal reactor LMR nor the high-temperature gas-cooled reactor HTGR is at major risk with regard to loss of coolant flow and perhaps not with regard to station blackout. The hazard is that reactor materials, sodium or graphite , could chemically react with air and water , causing what is known as an exothermic reaction that releases large amounts of heat in addition to the decay heat already existing within the core region. A powerful earthquake shook all units at the plant, initiating an automatic shutdown, or scram. Immediately after the earthquake, all safety systems in each unit were operable, though a few were slightly damaged. However, less than one hour after the earthquake, a tsunami struck the shoreline where the reactor units were built. The tsunami reached heights much greater than the reactors were designed to withstand, and ultimately it cut off the main power supply to the facility and damaged the backup generators by flooding their housing structures. Although the reactors withstood both an earthquake and a tsunami beyond their design requirement, the prolonged power outage drained backup batteries incorporated into the emergency core-cooling system, which led to a loss of capability to remove decay heat. As workers struggled to cool and stabilize the three cores by pumping seawater and boric acid into them, government officials established a km mile evacuation zone around the plant. Approximately one month after the initiating event, the reactor cores were stabilized, cracks in the foundations of the containment vessels were sealed, and irradiated cooling water began to be pumped to a storage building until it could be properly treated. Two of the damaged containment buildings at the Fukushima Daiichi nuclear power plant, northeastern Fukushima prefecture, Japan, several days after the March 11, , earthquake and tsunami that crippled the installation. Tokyo Electric Power Co. The risk associated with an earthquake of plausible magnitude is minimized by building plants away from faults and by making use of earthquake-resistant mechanical design and construction features. Furthermore, the addition of dikes and water barriers reduces the risk of damage by a tsunami. Added construction features such as water barriers must be able to withstand both an earthquake and a tsunami, as these are likely to be coupled events. However, because the plants were not designed to handle the natural disaster that took place, fault can be found with the design process, in a sense pointing out human error once again as the most failure-prone component in the nuclear industry. In the United States, the NRC has an emergency classification system that identifies four levels of severity in conditions at a nuclear power plant: A man is checked for radiation exposure after having been evacuated from the quarantine area around a nuclear power station in Fukushima prefecture, Japan, that was damaged in the March 11, , earthquake and tsunami. Potential degradation in the level of safety of the plant, but no release of radioactive material requiring off-site response or monitoring. Actual or potential substantial degradation in the level of safety of the plant, with a release of radioactive material from the plant expected. Actual or likely major failures of plant functions needed for protection of the public, with radioactivity levels potentially above acceptable thresholds at the boundary of the power plant.

Actual or imminent substantial core damage or melting of reactor fuel with the potential for loss of containment integrity; radioactive material is released and may be above acceptable thresholds beyond the boundary of the power plant. The INES offers a common event scale for all parties that interact with nuclear power or radiological sources in any part of the world. The seven levels and some of the important criteria are as follows: Minor problems with safety components, with significant defense-in-depth remaining. Significant contamination within the facility into an area not expected by design, with exposure of a worker in excess of the statutory annual limits. Severe contamination in an area not expected by design, with a nonlethal health effect such as a burn on a worker from radiation. Accident with local consequences. Fuel melt or damage to fuel resulting in more than 0. Accident with wider consequences. Severe damage to reactor core; release of large quantities of radioactive material within an installation, with a high probability of significant public exposure and several deaths from radiation. Significant release of radioactive material likely to require implementation of planned countermeasures. Major release of radioactive material with widespread health and environmental effects requiring implementation of planned and extended countermeasures. The nuclear fuel cycle No discussion of nuclear power is complete without a brief exposition of the nuclear fuel cycle. The whole point of a reactor is, after all, to initiate and control the process of fission on a very large scale in nuclear fuel, and the low cost of fueling is the chief reason for the economic competitiveness of nuclear power. The principal steps of the fuel cycle include uranium mining and extraction from its ore processing , uranium enrichment, fuel fabrication, loading and irradiation in the reactor fuel management , unloading and cooling, reprocessing, waste packaging, and waste disposal. The nuclear fuel cycle also is an integral step in the production of plutonium for nuclear weapon s, and the technologies of enrichment and reprocessing in particular have been key factors in the proliferation of these weapons around the world. For this reason and also for a host of other political, environmental, and economic reasons, the various steps in the nuclear fuel cycle are closely regulated and frequently observed under terms of international treaties. Uranium mining and processing Uranium is extracted from ores whose uranium content is often less than 0. Most ore deposits occur at or near the surface; whether they are mined through open-pit or underground techniques depends on the depth of the deposit and its slope. The mined ore is crushed and the uranium chemically extracted from it at the mouth of the mine. The residue remains naturally radioactive, as it contains long-lived radioactive daughter nuclei of uranium and has to be carefully managed to minimize the release of radioactive contaminants into the environment. The uranium concentrate, which is known as yellow cake, consists of uranium compounds typically 75 to 95 percent. It is shipped to a chemical plant for further purification and chemical conversion. Enrichment Several enrichment techniques have been developed, though only two of these methods are used on a large scale; these are gaseous diffusion and gas centrifuging. In gaseous diffusion , natural uranium in the form of uranium hexafluoride gas UF6 , a product of chemical conversion, is encouraged through a mechanical process to seep through a porous barrier. The molecules of UF6 penetrate the barrier slightly faster than those of UF6. Since the percentage of U increases by only a very small amount after traversal of the barrier, the process must be repeated over and over in thousands of stages to obtain the necessary enrichment for commercial nuclear power use. In gas centrifuging, the UF6 gas is fed into a high-speed centrifuge. The centrifuge is balanced very well at the top bottom and spins at an extremely high rate. Because of the relative centripetal forces that each atom experiences, the lighter species of this mixture of gaseous molecules, including U, tend to concentrate near the centre of the spinning centrifuge, while the heavier ones accumulate along the wall. These mixtures are then siphoned off. The degree of enrichment per stage in a centrifuge is greater than that obtained in a gaseous diffusion chamber , and the process uses less energy than gaseous diffusion does, but centrifuges are more expensive pieces of equipment. An experimental enrichment method with much commercial potential is laser separation. This process is based on the principle that isotope s of different molecular weight absorb light of different frequencies. Once a specific isotope has absorbed radiation and has reached an excited state, its properties may become quite different from the other isotopes; it is then separated on the basis of this difference. In one method known generically as MLIS

molecular laser isotope separation â€”or commercially as SILEX separation of isotopes by laser excitation â€”gaseous UF6 is exposed to high-powered lasers tuned to the correct frequencies to cause the molecules containing U but not U to lose electron s. In this ionized form, the U-containing molecules are separated from the stream on the basis of their different electric charge. Proponents of laser separation claim that the method consumes less energy and wastes less starting material than, for example, gaseous diffusion. Fabrication This step involves the conversion of the suitably enriched product material to the chemical form desired for reactor fuel. The only fuel fabricated on a large scale is for light-water reactors LWRs. The chemical form prepared for the LWR is uranium dioxide. Produced in the form of a ceramic powder, this compound is ground to a very fine flourlike consistency and inserted into a die, where it is pressed into a pellet shapeâ€”in the case of some LWR fuels, approximately 6 mm in diameter and 10 mm in length that is, about 0. This sintering, similar to the firing of other ceramic ware, produces a dense ceramic pellet. The pellets are loaded into prefabricated zirconium alloy cladding tubes, which are then filled with an inert gas and welded shut. Once the zirconium alloy tubes have been sealed, they go through significant testing to verify that there are no leaks.

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Chapter 2 : Nuclear reactor - Wikipedia

Recognizing the roles of heat and mass transfer in all aspects of fission-product behavior in sever reactor accidents, the Executive Committee of the International Centre for Heat and Mass Transfer organized a Seminar on Fission Product Transport Processes in Reactor Accidents.

How to cite this article: From Source to Environment. Journal of Environmental Science and Technology, 3: The most important source of artificially created radionuclides is neutron-induced nuclear fission. The chemical and physical forms of the active species determine deposition, migration and uptake are radioactivity by living organisms. A variety of systems and processes may introduce radioactivity into the environment. Human activities involving nuclear weapons and the nuclear fuel cycle including mining, milling, fuel enrichment and fabrication, reactor operation, spent fuel storage and reprocessing and waste storage , leading to significant creation and release of radioactivity. The physical and chemical form of radionuclides may vary depending on the release and transport conditions in addition to the element properties. A general distinction can be made between gases, aerosols and particulate material Warner and Harrison, The discussion of fission product released has been divided as follows Sich, ; Lewis, Volatile Fission Products VFP During normal conditions most of the FP resides within the fuel lattice as small gas bubbles, as small inclusion, or in some cases as solid solutions. As the temperature of the fuel increases, the gas bubbles tend to grow in size and, with other impurities, migrate out of the lattice Kelber, Such products may reside in the gap between the cladding and the fuel, if the cladding has been damaged, FP escape into the local atmosphere of the fuel rod, then FP macroscopically transported by the steam flow through the reactor core and primary system. The solid solution may also change form with temperature and similar migration occurs Suh and Hammerslely, The release rates of Kr, Xe, I and Cs are generally similar in magnitude at high temperature. This also supported by Kelber , who believed that the actual release and transport of FP within the reactor is a complex process involving the temperature history of the fuel, as well as the chemical and physical form of the FP and the fuel. These VFP in the fuel-cladding gap and grain boundaries are predominantly long half life nuclides, while the shorter half lives are predominately intragranular Osetek et al. In trace irradiated fuel, VFP probably diffuse as individual atoms and in higher burnup fuels they most likely are swept out in bubbles containing a mix of species Rest et al. Diffusion depends on the birth rate, the behavior of its precursor and decay chain despite that all the isobar decay chains of the fission products are more or less strongly interlinked Gardani and Ronchi, Some think of VFP in different way, Andriesse assumed that only few VFP will be released by the fuel and that most of them will be held back, even in the event of extreme accident. Released material was collected and analyzed both on line and after the test. Release of Te was found to be strongly dependent on the extent of cladding oxidation, indicating the existence of a Zr-Te alloy or compound. FP were found together without ordinary chemical compounds of these FP. Studies of the fuel and cladding microstructure showed a correlation between the amount of fuel porosity and fractional of volatile fission products. The calculations indicate that the isotopic release rate behavior is strongly dependent on whether the isotope is relatively long or short half lived Rest et al. Turnbull and White stressed on the fact that fission gas atoms are generated uniformly throughout the fuel and they diffuse to grain boundaries by single atom diffusion. In accord with observations, it is assumed that small fission gas bubbles are nucleated in the wake of energetic fission fragments and that they grow by the accumulation of single gas atom. According to Morris and Richard and Dawson , a fraction of FP generated within the fuel during reactor operation, escapes to the interspace of the fuel pin either as a result of recoil, or by diffusion, if the fuel temperature is sufficiently high in the mid of fuel pin. The only elements assumed to be released are the nuclides of Kr, Xe, I and Cs. While Ang predicted the following fractions of activity, via design bases leakage, released from the containment to the environment: The single release rate method which is particularly justifiable for the fast melt sequences, in which phase change from solid to liquid, not diffusion is the principal release mechanism UKAEA, This approach is

consistent with view of Hosemann , who stated that, It is simply wrong to assume that in the course of a core melt down, first the more highly volatile and latter the less volatile FP will be released in the containment. Experimentally the release rate observe for Ru was nearly the same as those for Xe, Kr and I at K, it was concluded that, in trace irradiated fuel, FP migrate as atoms via volume and grain boundary diffusion to the surface of the fuel from which they are vaporized Prussin et al. While Capone et al. The release rates at low temperatures, KK, the release rates were markedly higher than those of rare gases. The amount of cesium released at lower temperatures is approximately five times greater Capone et al. The LVFP is characterized by subtitutional transport with relatively high activation energy and diffusion entropy, these products are bound by either oxygen or uranium Andriesse, Chemical Forms An area that remains relatively poorly explored but is potentially important, is chemical interactions between fission products vapors and aerosols Malinauskas and Bell, This interaction could be expected to be significant because of the high temperature s and could affect the source term by changing the deposition revaporization behavior of certain nuclides Hobbines et al. So, much work remains to be done on the determination of the chemical species released from the fuel and the modeling of the migration of the species within the fuel Sich, ; Malinauskas and Kress, It has been shown that a particle number density of 5x per m3 is possible, which implies a particle surface area of m2 per m3 and so, one might expect chemical interaction between vapors and aerosols to be very important Butland and Kuhlman, Little experimental information is available on the chemical forms of radionuclides released from the fuel. Such information would be helpfull in understanding released rate from the fuel that affect radionuclides transport Kelber, Sr and Ba appear as soluble oxides. Unexpectedly high vapor pressures cannot be exerted by rare-earth oxides and have been attributed to the formation of monoxides e. Specific uncertainties are associated with the timing of radioactive release and the chemical species formed. The phrase regarding very large uncertainties proved to be the basis for much of the following work on FP release Morris and Richard, ; Taleyarkhan, Experiments have been undertaken to assess chemical aspects of fission product transport in the primary circuit of a Light Water Reactor LWR under severe accident conditions. These studies with stimulants have highlighted specific chemical effects that will influence the release of important fission products to the environment: CsI reacts with boric acid to generate cesium borates and volatile hydrogen iodide. Cesium hydroxide reacts with stainless steel with the formation of isolated cesium cations in the chromial lattice of the oxidized steel. The release of Te, Sr and Ba are dependent upon the degree of zircaloy oxidation and possible reactions with steam. These results illustrate only a few of the chemical reactions which may occur during a severe reactor accident Bowsher et al. According to Donahue et al. Aerosol Generation It is generally recognized that aerosols generated in-vessel, due to vaporized materials condensation in a relatively cold containment atmosphere, interact with FP vapors and play a significant role in the subsequent transport and possibly deposition of these FP Lee and Wu, Aerosols can be generated from control materials structural materials, fuel rod materials and fission products Malinauskas and Kress, ; Kelber, ; Butland and Kuhlman, ; Parker et al. Also because of less clear situation with Ba, Sr and Ru releases, Butland and Khulman assumed that these radionuclides are released as aerosols. Cd is clearly released as vapor, it is therefore not likely to be correct to assume it is released from the core as an aerosol, unless it reacts soon after release to form a condensable species. In-vessel aerosols generation is one of the least understood areas in the source term science. Preliminary results indicated that aerosols were generated continuously over the time of FP release Hobbines et al. Others believe that the VFP vapors along with vaporized core structure will condense onto internal surface or aerosolize Donahue et al. Whereas, Dawson assumed that in an oxygen rich atmosphere, for UO2 to oxidize to such an extent that, the U3O8 phase is reached, an expansion of the oxidation product takes place which leads to surface cracking and particular spallation. This process gives rise to a major source of activity for any fault. The formation of U3O8, which can not be formed in normal reactor operating conditions, is accompanied by a partial or total release, in molecular form, of the fission inventory of some nuclides in the oxidized portion of the fuel. The main elements of interest are the volatile nuclides: I, Cs and the noble gases together the Ru which becomes volatile, most probably as RuO4 Dawson, The examples

are from Chernobyl, TMI and Windscale accidents in addition to planned releases from reactor operations and fuel reprocessing plant. Radionuclides Inventory Radionuclides released into atmosphere are subjected to a variety of physical processes that determine their fate. These processes are complicated and poorly understood Warner and Harrison, and affected by physical and chemical forms of the radionuclides. After the extensive and surprising Chernobyl releases of radioactive materials Kress et al. The diversity of results indicate the considerable uncertainly, in estimating scale transport, expected by Miller , which may have been some what obscured in the Chernobyl situation by the prolonged nature of release. The accuracy of these models decreases markedly with increasing travel time and is normally considered very unreliable beyond about 72 h, although the material took 8 days to cross Europe Warner and Harrison, , but we may consider the field results as a qualitative data. The review made by Khan on the international data on Chernobyl accident indicated that the release estimation of noble gases, halogens, tellurium and alkali metals have a very high degree of uncertainty. The review revealed that, although much data have been gathered, there is a limited scope of validation of the results by different investigators. Indeed, one of the great puzzles of the Chernobyl source term is how to explain the simultaneous release of relatively large fraction of Ru, Ba, Ce Kress et al. The nonvolatile Ce and Ba were found by Demin and Khodakvsky to greatly enrich the analyzed hot particles. Ru assumed that it was exposed to highly oxidizing atmosphere to compose RuO3 and RuO4 which are highly volatile Borovoi and Sich, , which then condensed to aerosols or hot particles of nearly pure ruthenium Warner and Harrison, i. The released percentage of different radionuclides inventories of Chernobyl reactor core according to Khan review, were as follow: Different volatility elements were found in different countries rather than former USSR.

DOWNLOAD PDF FISSION PRODUCT TRANSPORT PROCESSES IN REACTOR ACCIDENTS

Chapter 3 : Fission Product Processes In Reactor Accidents : J. T. Rogers :

This book contains chapters explaining fission product transport processes in reactor accidents. Included are the following chapters: a generic overview of severe accident phenomena, the chemistry.

Nuclear reactor physics An example of an induced nuclear fission event. A neutron is absorbed by the nucleus of a uranium atom, which in turn splits into fast-moving lighter elements fission products and free neutrons. Though both reactors and nuclear weapons rely on nuclear chain-reactions, the rate of reactions in a reactor occurs much more slowly than in a bomb. Just as conventional power-stations generate electricity by harnessing the thermal energy released from burning fossil fuels , nuclear reactors convert the energy released by controlled nuclear fission into thermal energy for further conversion to mechanical or electrical forms. Nuclear fission When a large fissile atomic nucleus such as uranium or plutonium absorbs a neutron, it may undergo nuclear fission. The heavy nucleus splits into two or more lighter nuclei, the fission products , releasing kinetic energy , gamma radiation , and free neutrons. A portion of these neutrons may later be absorbed by other fissile atoms and trigger further fission events, which release more neutrons, and so on. This is known as a nuclear chain reaction. To control such a nuclear chain reaction, neutron poisons and neutron moderators can change the portion of neutrons that will go on to cause more fission. Some experimental types of reactor have used beryllium , and hydrocarbons have been suggested as another possibility. The kinetic energy of fission products is converted to thermal energy when these nuclei collide with nearby atoms. The reactor absorbs some of the gamma rays produced during fission and converts their energy into heat. Heat is produced by the radioactive decay of fission products and materials that have been activated by neutron absorption. This decay heat-source will remain for some time even after the reactor is shut down. A kilogram of uranium U converted via nuclear processes releases approximately three million times more energy than a kilogram of coal burned conventionally 7. The heat is carried away from the reactor and is then used to generate steam. Most reactor systems employ a cooling system that is physically separated from the water that will be boiled to produce pressurized steam for the turbines , like the pressurized water reactor. However, in some reactors the water for the steam turbines is boiled directly by the reactor core ; for example the boiling water reactor. Nuclear reactor control , Nuclear reactor physics , Passive nuclear safety , Delayed neutron , Iodine pit , SCRAM , and Decay heat The rate of fission reactions within a reactor core can be adjusted by controlling the quantity of neutrons that are able to induce further fission events. The fastest method for adjusting levels of fission-inducing neutrons in a reactor is via movement of the control rods. Control rods are made of neutron poisons and therefore tend to absorb neutrons. When a control rod is inserted deeper into the reactor, it absorbs more neutrons than the material it displacesâ€”often the moderator. Conversely, extracting the control rod will result in an increase in the rate of fission events and an increase in power. The physics of radioactive decay also affects neutron populations in a reactor. One such process is delayed neutron emission by a number of neutron-rich fission isotopes. These delayed neutrons account for about 0. The fission products which produce delayed neutrons have half lives for their decay by neutron emission that range from milliseconds to as long as several minutes, and so considerable time is required to determine exactly when a reactor reaches the critical point. Keeping the reactor in the zone of chain-reactivity where delayed neutrons are necessary to achieve a critical mass state allows mechanical devices or human operators to control a chain reaction in "real time"; otherwise the time between achievement of criticality and nuclear meltdown as a result of an exponential power surge from the normal nuclear chain reaction, would be too short to allow for intervention. This last stage, where delayed neutrons are no longer required to maintain criticality, is known as the prompt critical point. There is a scale for describing criticality in numerical form, in which bare criticality is known as zero dollars and the prompt critical point is one dollar, and other points in the process interpolated in cents. In some reactors, the coolant also acts as a neutron moderator. A moderator increases the power of the reactor by causing the fast neutrons that are released from fission to lose energy and become thermal

neutrons. Thermal neutrons are more likely than fast neutrons to cause fission. A higher temperature coolant would be less dense, and therefore a less effective moderator. In other reactors the coolant acts as a poison by absorbing neutrons in the same way that the control rods do. In these reactors power output can be increased by heating the coolant, which makes it a less dense poison. Nuclear reactors generally have automatic and manual systems to scram the reactor in an emergency shut down. These systems insert large amounts of poison often boron in the form of boric acid into the reactor to shut the fission reaction down if unsafe conditions are detected or anticipated. The common fission product Xenon produced in the fission process acts as a neutron poison that absorbs neutrons and therefore tends to shut the reactor down. Xenon accumulation can be controlled by keeping power levels high enough to destroy it by neutron absorption as fast as it is produced. Fission also produces iodine , which in turn decays with a half-life of 6. When the reactor is shut down, iodine continues to decay to xenon, making restarting the reactor more difficult for a day or two, as the xenon decays into cesium, which is not nearly as poisonous as xenon, with a half-life of 9. This temporary state is the "iodine pit. As the extra xenon is transmuted to xenon, which is much less a neutron poison, within a few hours the reactor experiences a "xenon burnoff power transient". Control rods must be further inserted to replace the neutron absorption of the lost xenon Failure to properly follow such a procedure was a key step in the Chernobyl disaster. For this reason many designs use highly enriched uranium but incorporate burnable neutron poison in the fuel rods. Electrical power generation[edit] The energy released in the fission process generates heat, some of which can be converted into usable energy. A common method of harnessing this thermal energy is to use it to boil water to produce pressurized steam which will then drive a steam turbine that turns an alternator and generates electricity. He filed a patent for his idea of a simple reactor the following year while working at the Admiralty in London. Lise Meitner and Otto Hahn in their laboratory. Inspiration for a new type of reactor using uranium came from the discovery by Lise Meitner , Fritz Strassmann and Otto Hahn in that bombardment of uranium with neutrons provided by an alpha-on-beryllium fusion reaction, a " neutron howitzer " produced a barium residue, which they reasoned was created by the fissioning of the uranium nuclei. The following year the U. Government received the Frischâ€”Peierls memorandum from the UK, which stated that the amount of uranium needed for a chain reaction was far lower than had previously been thought. Eventually, the first artificial nuclear reactor, Chicago Pile-1 , was constructed at the University of Chicago , by a team led by Italian physicist Enrico Fermi , in late By this time, the program had been pressured for a year by U. The Chicago Pile achieved criticality on 2 December [12] at 3: Soon after the Chicago Pile, the U. The primary purpose for the largest reactors located at the Hanford Site in Washington , was the mass production of plutonium for nuclear weapons. Fermi and Szilard applied for a patent on reactors on 19 December Atomic Energy Commission produced 0. Besides the military uses of nuclear reactors, there were political reasons to pursue civilian use of atomic energy. This diplomacy led to the dissemination of reactor technology to U. Research by the Army and the Air Force never came to fruition; however, the U.

Chapter 4 : Nuclear Fission Products: From Source to Environment

The International Centre for Heat and Mass Transfer organized a seminar focusing of Fission Product Transport Processes in Reactor Accidents, conducted at Yugoslavia in This book contains the proceedings of the seminar, which provided a forum for examining fisson-product.

Fission product yield Fission product yields by mass for thermal neutron fission of U , Pu , a combination of the two typical of current nuclear power reactors, and U used in the thorium cycle. Each fission of a parent atom produces a different set of fission product atoms. However, while an individual fission is not predictable, the fission products are statistically predictable. While fission products include every element from zinc through the lanthanides , the majority of the fission products occur in two peaks. One peak occurs at about expressed by atomic number strontium to ruthenium while the other peak is at about tellurium to neodymium. The yield is somewhat dependent on the parent atom and also on the energy of the initiating neutron. In general the higher the energy of the state that undergoes nuclear fission, the more likely that the two fission products have similar mass. The curves for the fission of the later actinides tend to make even more shallow valleys. In extreme cases such as Fm , only one peak is seen. The adjacent figure shows a typical fission product distribution from the fission of uranium. Note that in the calculations used to make this graph, the activation of fission products was ignored and the fission was assumed to occur in a single moment rather than a length of time. In this bar chart results are shown for different cooling times â€” time after fission. Note that the curve against mass number is smooth. The microscopic tracks left by these fission products in some natural minerals mainly apatite and zircon are used in fission track dating to provide the cooling crystallization ages of natural rocks. The technique has an effective dating range of 0. These fission products were important in providing proof that the natural reactor had occurred. Fission products are produced in nuclear weapon explosions, with the amount depending on the type of weapon. The largest source of fission products is from nuclear reactors. Most of these fission products remain in the fuel unless there is fuel element failure or a nuclear accident , or the fuel is reprocessed. Spent nuclear fuel In commercial nuclear fission reactors , the system is operated in the otherwise self-extinguishing prompt subcritical state. The reactor specific physical phenomena that nonetheless maintains the temperature above the decay heat level, are the predictably delayed, [5] and therefore easily controlled, transformations or movements of a vital class of fission product, or reaction ember, as they decay, [6] with Bromine being one such long-lived "ember", with a half-life of about a minute and thus it emits a delayed neutron upon decay. In an analogous manner to fire dampers varying the opening to control the movement of wood embers towards new fuel, control rods are comparatively varied up or down, as the nuclear fuel burns up over time. Fission products are the largest source of radioactivity for the first several hundred years, while actinides are dominant roughly to years after fuel use. Fission occurs in the nuclear fuel, and the fission products are primarily retained within the fuel close to where they are produced. These fission products are important to the operation of the reactor because some fission products contribute delayed neutrons that are useful for reactor control while others are neutron poisons that tend to inhibit the nuclear reaction. The buildup of the fission product poisons is a key factor in determining the maximum duration a given fuel element can be kept within the reactor. The decay of short-lived fission products also provide a source of heat within the fuel that continues even after the reactor has been shut down and the fission reactions stopped. It is this decay heat that sets the requirements for cooling of a reactor after shutdown. If the fuel cladding around the fuel develops holes, then fission products can leak into the primary coolant. Depending on the fission product chemistry, it may settle within the reactor core or travel through the coolant system. Coolant systems include chemistry control systems that tend to remove such fission products. In a well-designed power reactor running under normal conditions, the radioactivity of the coolant is very low. It is known that the isotope responsible for the majority of the gamma exposure in fuel reprocessing plants and the Chernobyl site in is Cs Iodine is one of the major radioactive elements released from reprocessing plants.

In nuclear reactors both Cs and strontium are found in locations remote from the fuel. Nuclear reactor poisons[edit] Main articles: Nuclear poison and Iodine pit Some fission products decay with the release of a neutron. Since there may be a short delay in time between the original fission event which releases its own prompt neutrons immediately and the release of these neutrons, the latter are termed " delayed neutrons ". These delayed neutrons are important to nuclear reactor control. Some of the fission products, such as xenon and samarium , have a high neutron absorption cross section. Since a nuclear reactor depends on a balance in the neutron production and absorption rates, those fission products that remove neutrons from the reaction will tend to shut the reactor down or "poison" the reactor. Nuclear fuels and reactors are designed to address this phenomenon through such features as burnable poisons and control rods. Build-up of xenon during shutdown or low-power operation may poison the reactor enough to impede restart or to interfere with normal control of the reaction during restart or restoration of full power, possibly causing or contributing to an accident scenario. Nuclear weapons[edit] Nuclear weapons use fission as either the partial or the main energy source. Depending on the weapon design and where it is exploded, the relative importance of the fission product radioactivity will vary compared to the activation product radioactivity in the total fallout radioactivity. The immediate fission products from nuclear weapon fission are essentially the same as those from any other fission source, depending slightly on the particular nuclide that is fissioning. However, the very short time scale for the reaction makes a difference in the particular mix of isotopes produced from an atomic bomb. Almost no Cs is formed by nuclear fission because xenon is stable. So in a momentary criticality by the time that the neutron flux becomes zero too little time will have passed for any Cs to be present. While in a power reactor plenty of time exists for the decay of the isotopes in the isobar to form Cs, the Cs thus formed can then be activated to form Cs only if the time between the start and the end of the criticality is long. After a few years, the radiation is dominated by strontium and caesium , whereas in the period between 10, and a million years it is technetium that dominates. Application[edit] Some fission products such as Cs are used in medical and industrial radioactive sources. In this way these metaloxo anions act as anodic corrosion inhibitors - it renders the steel surface passive. The formation of 99TcO2 on steel surfaces is one effect which will retard the release of 99Tc from nuclear waste drums and nuclear equipment which has become lost prior to decontamination e. In a similar way the release of radio-iodine in a serious power reactor accident could be retarded by adsorption on metal surfaces within the nuclear plant. The portion of the total radiation dose in air contributed by each isotope versus time after the Chernobyl disaster , at the site thereof. The threat becomes smaller with the passage of time. Locations where radiation fields once posed immediate mortal threats, such as much of the Chernobyl Nuclear Power Plant on day one of the accident and the ground zero sites of U. Many of the fission products decay through very short-lived isotopes to form stable isotopes , but a considerable number of the radioisotopes have half-lives longer than a day. Later 90Sr and Cs are the main radioisotopes, being succeeded by 99Tc. In the case of a release of radioactivity from a power reactor or used fuel, only some elements are released; as a result, the isotopic signature of the radioactivity is very different from an open air nuclear detonation , where all the fission products are dispersed. Fallout countermeasures[edit] The purpose of radiological emergency preparedness is to protect people from the effects of radiation exposure after a nuclear accident or bomb. Evacuation is the most effective protective measure. However, if evacuation is impossible or even uncertain, then local fallout shelters and other measures provide the best protection. At least three isotopes of iodine are important. Open air nuclear testing and the Chernobyl disaster both released iodine The short-lived isotopes of iodine are particularly harmful because the thyroid collects and concentrates iodide â€” radioactive as well as stable. Absorption of radioiodine can lead to acute, chronic, and delayed effects. Acute effects from high doses include thyroiditis , while chronic and delayed effects include hypothyroidism , thyroid nodules , and thyroid cancer. It has been shown that the active iodine released from Chernobyl and Mayak [17] has resulted in an increase in the incidence of thyroid cancer in the former Soviet Union. One measure which protects against the risk from radio-iodine is taking a dose of potassium iodide KI before exposure to radioiodine. A low-cost alternative to commercially available iodine

pills is a saturated solution of potassium iodide. Long-term storage of KI is normally in the form of reagent grade crystals. Perchlorate ions, a common water contaminant in the USA due to the aerospace industry , has been shown to reduce iodine uptake and thus is classified as a goitrogen. Perchlorate ions are a competitive inhibitor of the process by which iodide is actively deposited into thyroid follicular cells. Studies involving healthy adult volunteers determined that at levels above 0. Perchlorate remains very useful as a single dose application in tests measuring the discharge of radioiodide accumulated in the thyroid as a result of many different disruptions in the further metabolism of iodide in the thyroid gland. In another related study where subjects drank just 1 litre of perchlorate-containing water per day at a concentration of 10 ppm, i. Studies of chronically exposed workers though have thus far failed to detect any abnormalities of thyroid function, including the uptake of iodine. The continual distribution of perchlorate tablets or the addition of perchlorate to the water supply would need to continue for no less than 80â€”90 days, beginning immediately after the initial release of radioiodine was detected. After 80â€”90 days passed, released radioactive iodine would have decayed to less than 0. However, in the event of a radioiodine release too massive and widespread to be controlled by the limited stock of iodide and iodate prophylaxis drugs, then the addition of perchlorate ions to the water supply, or distribution of perchlorate tablets would serve as a cheap, efficacious, second line of defense against carcinogenic radioiodine bioaccumulation. The ingestion of goitrogen drugs is, much like potassium iodide also not without its dangers, such as hypothyroidism. In all these cases however, despite the risks, the prophylaxis benefits of intervention with iodide, iodate, or perchlorate outweigh the serious cancer risk from radioiodine bioaccumulation in regions where radioiodine has sufficiently contaminated the environment. Cesium[edit] The Chernobyl accident released a large amount of cesium isotopes which were dispersed over a wide area. Plants with shallow root systems tend to absorb it for many years. Hence grass and mushrooms can carry a considerable amount of Cs, which can be transferred to humans through the food chain. One of the best countermeasures in dairy farming against Cs is to mix up the soil by deeply ploughing the soil. This has the effect of putting the Cs out of reach of the shallow roots of the grass, hence the level of radioactivity in the grass will be lowered. Also the removal of top few centimeters of soil and its burial in a shallow trench will reduce the dose to humans and animals as the gamma photons from Cs will be attenuated by their passage through the soil. The deeper and more remote the trench is, the better the degree of protection. Fertilizers containing potassium can be used to dilute cesium and limit its uptake by plants. In livestock farming, another countermeasure against Cs is to feed to animals prussian blue. This compound acts as an ion-exchanger. The cyanide is so tightly bonded to the iron that it is safe for a human to consume several grams of prussian blue per day. The prussian blue reduces the biological half-life different from the nuclear half-life of the cesium. The physical or nuclear half-life of Cs is about 30 years. Cesium in humans normally has a biological half-life of between one and four months. An added advantage of the prussian blue is that the cesium which is stripped from the animal in the droppings is in a form which is not available to plants.

Chapter 5 : MATADOR, Fission Products Release and Deposition in LWR Containment, Meltdown Accider

This report presents a study of fission product transport behavior in N Reactor during a severe accident. More detail about fission product behavior than has previously been available is provided and key parameters that control this behavior are identified.

Chapter 6 : Nuclear fission product - Wikipedia

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