Glossary to "365 reasons against atomic energy"

by Dr Helmut Hirsch, scientific consultant in nuclear safety and risk research. Translated by Barbara Ranzenhofer.

Aerosols

Also called particulates, they are tiny solid or liquid particles in the air. Fine particles that are small enough can penetrate directly into the lungs when inhaled. Therefore, radioactive materials like → plutonium are so hazardous.

Alpha emitter, alpha radiation

Some → radionuclides, most of them heavy nuclei, are alpha emitters. They emit so-called alpha particles, which are helium-4 nuclei, the nuclei of an → isotope of the noble gas helium with two protons and two neutrons.

Alpha radiation can easily be shielded, but is very dangerous if alpha emitters get into the body through food or by inhaling - for example after a radioactive cloud is released in a reactor accident.

Atomic bomb, nuclear weapon

Weapon with great destructive force which obtains its energy from the fission of uranium-235 (→ uranium) and plutonium-239 (→ plutonium). (Theoretically also uranium-233, which has not yet been produced in larger quantities, could be used.) At the ignition of an atomic bomb an uncontrolled → nuclear chain reaction is started.

Using state-of-the-art technology, a plutonium bomb can be built with 2-4 kg Pu-239, a uranium bomb with less than 15 kg U-235. The explosive force of an atomic bomb is given as the amount of the chemical explosive TNT that would release the same amount of energy when exploded (TNT-equivalent in 1000 tons (kilotons, kt) or million tons (megatons, Mt)). The detonation of an atomic bomb has a three-fold effect: by radiation, heat and blast wave.

The first atomic bomb of all times was detonated on July 16, 1945, during the "Trinity" tests in New Mexico. It was a plutonium bomb with an explosive force of 21 kt. On August 6, 1945, the Japanese city Hiroshima was destroyed by a uranium bomb (13 kt), and on August 9, 1945, the city Nagasaki by a plutonium bomb (22 kt). Since then there has been no military use, but numerous → nuclear weapons tests.

An atomic bomb is a nuclear weapon dropped as a bomb from a plane. The more general term "Nuclear weapon" includes atomic bombs and thermonuclear explosives (→ hydrogen bombs).

Auxiliary service water system, - pump

Cooling system consisting of pipes, coolers and pumps which is needed in normal reactor operation but has also important safety-related functions. It is essential for heat removal after certain accidents.

Becquerel, terabecquerel

Unit of the activity of radioactive materials. 1 becquerel means that in that quantity of radioactive material one nucleus decays per second. 1 billion becquerel is denominated a terabecquerel; this unit is apt for measuring the amount of radioactive release in accidents.

Symbols: Bq and TBq

Beta emitter, beta radiation

Some → radionuclides are beta emitters. They emit so-called beta particles; these are → electrons with negative or positive charge.

Beta radiation is less penetrating than → gamma radiation, but harder to shield than → alpha radiation. If beta emitters are released in a reactor accident, they can damage the human body from the outside by radiation and also from the inside if they are ingested or inhaled.

Boiling water reactor, BWR

Reactor type (→ reactor) which was developed from the → pressurized water reactor, sub-type of the → light-water reactor. The second most common reactor type in operation worldwide after the → PWR. In the BWR, steam is generated in the reactor core and conducted directly to the turbine.

A BWR is more difficult to control than a PWR, as liquid water and steam are both present in the core. Therefore, instabilities in the → neutron flux in the → reactor core can occur, leading to local fluctuations in output.

Boron, boric acid

The element boron (chemical symbol B) has two stable → isotopes, of which ^{10}B is a good neutron absorber. It is used in the form of boric acid to control the → nuclear chain reaction in the → reactor and also to keep the reactor subcritical (i.e. to prevent a chain reaction). It is therefore of vital importance to maintain the required boron concentration in the water that is fed into the reactor.

Boron "poisoning" is also often mentioned in this context.

Caesium source

see Radiation source

CANDU

CANadian Deuterium Uranium reactor. Canadian reactor type (→ reactor) that uses natural uranium as → fuel and → heavy water as → moderator and coolant. The CANDU does not have a compact → reactor core located in a → reactor pressure tank, but the fuel bundles are inserted into pressure tubes cooled by a flow of heavy water and in a heavy-water tank.

Like a → pressurized water reactor, a CANDU is equipped with two coolant loops connected by → steam generators. The → primary coolant is under such high pressure that the heavy water in it does not start to boil.

Due to the high number of pressure tubes the primary coolant of a CANDU has a very complicated structure. The walls of the pressure tubes are exposed to a greater → neutron flux than the reactor pressure tank of a pressurized water reactor. This leads to considerable problems with materials.

Chemical explosion

Chemical reaction that occurs very fast and leads to a considerable release of energy. Not to be confounded with a nuclear explosion (uncontrolled chain reaction as in an → atomic bomb); the effect of a chemical explosion is weaker, although it can be very destructive.

In nuclear technology, chemically explosive materials are mainly used in liquid form in → fuel reprocessing plants. A chemical explosion in such a plant can lead to the release of radioactive materials.

Cladding tube

see Fuel assembly

Containment

Largely gas-tight structure enclosing the → reactor core and the pipework and components that belong to the core. In a → pressurized water reactor, for instance, the entire → primary coolant circuit is enclosed in the containment. The containment is also often called (reactor) safety containment.

Piping in the containment is equipped with rapidly closing valves and access to the containment is through airlocks. In case of an accident, steam that leaks from the reactor vessel is prevented from leaking into the atmosphere but is contained in the containment where it condenses into water which is collected in the so-called sump and can then be re-used as coolant.

In a serious accident the containment can be destroyed, for instance because of sudden pressure peaks (as may occur in a hydrogen explosion or in the event that the → reactor pressure tank melts down due to high internal pressure) or, on the other hand, because of overpressure that builds up gradually. Moreover, in case of a failure in the heating pipes of a → steam generator, the containment is bypassed. It is also ineffective in case of a failure in the isolation valves.

Contamination, contaminated

People, buildings, areas, machines, rooms, water, air... can be contaminated by radioactive materials.

Control rod

To control the chain reaction in a → reactor. It contains materials that absorb → neutrons, e.g. → boron. The further the control rod is inserted into the → reactor core, the more neutrons are absorbed and the lower the capacity of the reactor.

These rods are needed, among other things, for a → reactor scram. If they seize or are inserted too slowly, severe accidents can occur.

Core configuration

Position of the → fuel bundles in the → reactor; also: process of positioning the fuel bundles in the → reactor core.

Core instability

Pressure and temperature of the coolant (cooling water) in the → reactor core affect the nuclear chain reaction. Particularly in → boiling water reactors, interaction can lead to oscillation in the neutron flux and consequently to instabilities in the core. These instabilities can cause the → cladding tubes of fuel bundles to get superheated and break.

Core instrumentation

Measuring instruments built into or in between the → fuel bundles in the → reactor core. With the (in-)core instrumentation the → neutron flux in the reactor core is measured in a wide performance range (from start-up to full power). A large percentage of measuring instruments covers the full-power sector, as for this range the distribution of the neutron flux in the reactor core must be known.

The reliable functioning of the (in-)core instrumentation is essential for the safe operation of a reactor.

Core meltdown, core meltdown accident

The shutdown of a reactor does not stop the heat production completely. Although the → nuclear chain reaction can be interrupted, the decay of the radioactive materials, large quantities of which are inside the → fuel bundles, can not be stopped. Without cooling a shutdown reactor heats up more and more because of this → decay heat until the fuel melts. In certain types of accidents this can happen already about an hour after the accident occurred.

Radioactive materials are released from the hot melt.

Core meltdown accidents in → light-water reactors can lead to releases that are even higher than in the accident in Chernobyl, e.g. in case of early containment failure. Other accident types lead to minor releases which are, however, still very damaging to the environment.

If the operating staff is successful in restoring a failed core cooling quickly, with some luck it is possible to prevent a melt or at least to stabilise the situation after a partial meltdown of the core. Even in the latter case radioactive releases can occur.

Corrosion

Corrosion is the deterioration of a material due to chemical reactions with substances in its environment, e.g. of a pipe in the → primary coolant due to a reaction with the coolant. Additional mechanical strain can accelerate corrosion (e.g. in the case of stress corrosion cracking).

There are many different types of corrosion, e.g. uniform corrosion, pitting, crevice corrosion and intergranular corrosion.

Criticality accident

Uncontrolled and unintentional → nuclear chain reaction. When dealing with fissile materials, extensive precautionary measures have to be taken in order to prevent chain reactions. Technical trouble or a human error - e.g. the allowed concentration of fissile material in solutions is exceeded, or → control rods are erroneously removed from a → reactor - can lead to criticality, i.e. a chain reaction starts. The environment is exposed to a shower of → neutrons.

Decay heat

During the operation of a reactor, 93% of the resulting heat is produced by the → chain reaction, the remaining 7% by the radioactive decay of radioactive materials in the → reactor core. This decay heat can not be disabled and is still produced even when the chain reaction has been stopped by a → reactor scram. The removal of this heat has to be guaranteed at all times; otherwise there is the risk of a core meltdown.

The decay heat decreases rapidly after the shutdown. After one day it has fallen from 7% to around 0.6% of the total heat during reactor operation, after one month to about 0.17%. However, in a large nuclear power plant the latter percentage still equals around 7000 kilowatts of power - more than enough to melt down the core without cooling.

Deuterium

see Hydrogen

Dose, dose of radiation

The dose (of radiation) is a measure for the absorbed amount of → ionizing radiation.

The absorbed dose indicates the absorbed radiation energy; it is a purely physical, i.e. measurable, unit and is measured in gray or milligray (Gy or mGy).

The equivalent dose is measured in sieverts or millisieverts (Sv or mSv). It is calculated on the basis of the absorbed dose and the relative biological effect of the type of radiation in question. (→ Neutron radiation, for example, is much more effective than → gamma radiation in the same absorbed dose.) The equivalent dose is not directly measurable; it is a purely mathematical variable with many uncertainties.

The effective dose is a measure for the total effect of exposure to radiation on the human organism. Giving doses for certain organs and tissues can also be useful (as for instance the iodine isotope → iodine-131 affects the thyroid in particular).

Limit values for the permissible dose are to keep the hazard through radiation on an acceptable level. In Germany, for instance, the limit for the yearly dose (effective dose) for an occupationally exposed person is set at 20 mSv; the limit for exposure to radiation in waste water and waste air emitted by nuclear plants for the general public is set at 0.3 mSv respectively.

A high dose leads to acute radiation sickness. Effects are felt from around 0.2 Sv, in sensitive people even below that value. A dose of 2 Sv can already be deadly, doses of over 6 Sv are virtually always lethal.

Lower doses lead to radiation injuries of a different kind - cancer, genetic defects and other diseases. These diseases occur according to the laws of statistics - the higher the dose, the higher the probability of disease. There is no lower limit for this type of effects ("stochastic health effects of radiation"). As a consequence, observing the limit values does not mean that no harm will be done.

Giving a percentage for the disease probability at a certain dose is difficult and subject to great uncertainties, which are due in part to knowledge gaps and in part to the fact that every individual reacts differently to radiation. Children are more sensitive than grown-ups, and women than men, and lastly there are also differences between individuals. The probability of developing cancer after being exposed to a radiation of 1 Sv is about 26% for women and about 18% for men, according to official sources (UNSCEAR - United Nations Scientific Committee on the Effects of Atomic Radiation, assuming a linear correlation between dose and effect).

The uncertainties are even greater with respect to genetic defects caused by radiation; it does not seem to be possible at present to give even approximate values.

Electron

Elementary particle that carries a negative electric charge. In an atom the electrons with negative charge revolve around the atom nucleus with positive electric charge; they make up the so-called electron sheath.

There are also electrons with positive electric charge, the so-called positrons.

Emergency cooling system, emergency cooling

The emergency cooling system is the cooling system of a → reactor which in case of a failure of the heat removal system serves to remove the → decay heat after the reactor has been shut down. Usually it is composed of various sub-systems; in a → PWR these would be a high pressure and a low pressure system (injection by pumps) and the hydraulic accumulators (injection by overpressure in tank).

The sub-systems of the emergency cooling system are again composed of various parallel lines (→ redundancy) to enhance safety. However, multiple failure with a single cause is possible (e.g. formation of gas-charged bladders in pumps). Furthermore, there are events - like the bursting of the → reactor pressure vessel - on which the emergency cooling system has no influence and which lead to → core meltdown regardless of a functioning emergency cooling system.

Emergency power system, emergency Diesel generator

A nuclear power plant needs a continuous and reliable power supply for vital safety systems. During operation of the reactor the power needed is diverged from the output of the reactor. If the → reactor is shut down, power is supplied by the grid.

If the connection to the grid breaks off while the reactor is in operation, a possible cause of action is to try to reduce the output to auxiliary station supply, although the odds are relatively high that this fails.

If the reactor has to be shut down while the plant is without connection to the grid, or if the connection to the grid breaks off when the reactor has already been shut down, the emergency power system is needed: the emergency Diesel generators of the emergency power system are switched on and supply the safety systems. There are more Diesel generators in stock than are necessary (→ redundancy). On the other hand, Diesel generator sets are susceptible to malfunction. Over longer periods of usage, for instance due to large-area disasters caused by bad weather, the provision with Diesel fuel can become a problem.

If in such a case the emergency Diesel generators break down or run out of fuel, a severe accident with → core meltdown is the result.

Emergency scram system

see Reactor scram

Emergency system, emergency power supply

The emergency system is to ensure the cooling of the → reactor in case of an accident caused by → external impact. In many power plants it is situated in a building apart with a separate water reserve, pipes to feed coolant into the coolant circuit of the reactor and (in → PWR) into the → steam generators and a separate emergency power supply (emergency generator).

The emergency system is not effective if the reactor building is fully destroyed and the cooling system severely damaged. Particularly in old plants it provides inadequate protection against external impact - especially against the scenario of a crash of a large commercial aircraft.

Enrichment, enrichment plant

see Uranium enrichment

External impact

In nuclear terminology, this term refers to dangers from the outside that can affect a nuclear power plant. External impacts include natural impacts like earthquakes, extreme weather conditions or biological sediments (clams, fish, jellyfish or water plants in cooling water extraction devices; leaves or insects in the vent system) on the one hand; on the other hand, they also include impacts resulting from human activity, e.g. the explosion of a passing gas tank or a plane crash caused by an accident.

Targeted assaults are not counted among the external impacts but are called "industrial sabotage" (in the case of terror and sabotage) or "enemy action" (in the case of war).

Fallout

Radioactive pollutants that are released into the atmosphere in a nuclear accident (or a → nuclear weapons test), are dispersed by the wind and then fall back down on the earth.

Fallout after a → core meltdown accident can cause severe contamination in areas many hundred kilometres away from the site of the accident and can be spread worldwide.

Fast breeder (reactor)

In a fast breeder → reactor the → nuclear chain reaction is sustained mainly by fast → neutrons. There is no → moderator to slow down the neutrons and consequently no neutron loss in the moderator. On the other hand, a fast reactor is more difficult to control.

The most important type of fast reactor at the moment is the fast breeder reactor (fast breeder). The basic idea behind this reactor type is to produce fissile plutonium-239 (→ plutonium) from the uranium isotope U-238 which is not suitable as nuclear fuel. If this principle was applied throughout, the world's uranium resources could theoretically be exploited a hundred times more efficiently.

However, the safety problems in a fast breeder are even greater than those of → light-water reactors. In a fast breeder, nuclear explosions can occur which lead to the destruction of the reactor building and to the distribution of large amounts of radioactive pollutants, especially plutonium, in the environment. Moreover, the coolant used is → sodium, which reacts violently with water and air.

A further problem of the fast breeder is that the plutonium produced is composed to a very high percentage of the → isotope Pu-239, a fact that renders it particularly suitable for the production of → nuclear weapons. That is to say that a fast breeder is especially vulnerable to be abused for military purposes.

Some decades ago, the breeder reactors were presented by the nuclear industry as the energy source of the future for which fuel resources would last thousands of years. But, due to the safety problems mentioned and the high costs of the technology, this reactor line did not assert itself. As of now, only three plants of this type are in operation. The fast breeder in Kalkar (Germany) was fully set up, but has never been put into operation.

Feedwater

see Steam generator

Filter resins

Different types of filters are used in nuclear power plants to purify the cooling water; among other types such that contain resins. When these filters have reached their capacity they have to be treated as → nuclear waste and disposed of accordingly.

Fissile materials, fissionable materials[1]

Materials whose nuclei are fissile by → neutrons; i.e. the nuclei are split into two or more parts by the impact of a neutron. In certain → isotopes of → uranium and → plutonium, the fission in turn releases more neutrons so that a → chain reaction can result.

Fuel

see Fuel assembly

Fuel assembly, fuel bundle

New fuel for nuclear power plants (enriched → uranium or a mix of uranium and → plutonium) is pressed into pellets. These are then filled into long cylindrical tubes (cladding tubes, mostly made of the zirconium alloy Zircalloy) to make the so-called fuel rods. Quite a large number of fuel rods (a few hundred in →

[1] "Fissile" is distinguished from "fissionable". "Fissionable" are any materials with atoms that can undergo nuclear fission. "Fissile" is defined to be materials that are fissionable by slow neutrons. "Fissile" thus, is more restrictive than "fissionable" — although all fissile materials are fissionable, not all fissionable materials are fissile.
Source: http://en.wikipedia.org/wiki/Fissile

pressurized water reactors) are bundled together to form a fuel assembly or bundle.
Fuel bundles can get damaged by excessively high temperatures, corrosion or other factors. Damage most often leads to leakage in the cladding tubes, which means release of radioactive materials.
A fuel bundle typically stays in a reactor during some years. Then they are highly radioactive, with intense radiation and heat development. In this state they are called spent fuel elements.

Fuel cooling installation, decay basin

A pool filled with water in or near the reactor building in which the → fuel assemblies are stored after use in the reactor. Only after a couple of years during which radioactivity has decayed (and heat development has decreased as a result) can the fuel assemblies be transported in containers and disposed of. The fuel cooling installation contains more long-lived radioactive materials than the → reactor core. In some reactor types (e.g. German product line 69 → boiling water reactors, part of US nuclear power plants), the protection of the basin against external impact is much worse than that of the reactor, which makes the basin especially vulnerable.

Full load, full-load operation

Full load means 100% of the capacity that a power plant can reach. Full-load operation is consequently operation at 100% of capacity.

Gamma emitter, gamma radiation

Electromagnetic radiation emitted by an atomic nucleus during radioactive decay. Gamma radiation is similar in its physical properties to light and microwave radiation, but with a higher energy and shorter wavelength. In nearly every instance of radioactive decay and nuclear fission, gamma radiation is emitted.

Gamma radiation is highly penetrating. After a reactor accident, for example, it particularly affects human beings in → contaminated areas from the outside. It is best shielded by materials with high density and a large number of → protons in the nucleus (i.e. with a high "atomic number").

Half-life

The period of time after which half of the atomic nuclei in a → radionuclide have decayed. Half-lives vary greatly between different nuclides. Uranium-238 (→ uranium) for example has a half-life of 4.47 million years. Caesium-137 (→ radiation source) has a half-life of 30.25 years, tritium of 13.33 years. There are also radionuclides with half-lives of a fraction of a second.

Heavy water

→ Hydrogen has different → isotopes. The atomic nucleus of the most frequent isotope has only one → proton. This isotope has the chemical symbol H and together with oxygen it forms normal water ("light water") H2O. Another non-radioactive isotope found in nature is deuterium whose nucleus has one proton plus one → neutron. The compound with oxygen, D2O, is called heavy water.

Heavy water absorbs fewer neutrons than light water, so it slows down a → nuclear chain reaction to a lesser extent. Some reactor types (→ reactor) are cooled and → moderated with heavy water (→ CANDU). The heavy water in a reactor is exposed to intense → neutron radiation. When deuterium captures a neutron, the radioactive isotope → tritium is produced, i.e. the heavy water turns radioactive.

Highly enriched uranium

see Uranium

High-pressure injection system

Part of the → emergency cooling system, e.g. in → PWR and → BWR.

Hotspot

Informal term for a relatively small area which in striking contrast to its surroundings is highly radioactively contaminated. A hotspot can emerge after an accident in a reactor, or after a nuclear weapons test.

Hydrogen

Hydrogen is the element with atomic number 1, i.e. the hydrogen core contains one → proton around which one → electron revolves. Hydrogen is flammable and explosive; a mixture of between 4 and 75% hydrogen with air is inflammable (detonating gas).

Hydrogen has three known → isotopes. Of these, normal ("light") hydrogen (nucleus composed of one proton) and "heavy" hydrogen (deuterium; nucleus composed of one proton and one neutron) are stable, while the heaviest isotope, → tritium (nucleus composed of one proton and two neutrons) is radioactive.

Hydrogen is often used in power plants for the cooling of large generators. Hydrogen cooling is more effective than air cooling and there is less friction loss; this is why the fire and explosion hazard (→ hydrogen explosion) is put up with.

Hydrogen bomb, thermonuclear explosive (device)

Weapon with great destructive force which derives its energy from the fusion of the atomic nuclei of the hydrogen isotopes deuterium and tritium (→ hydrogen). A hydrogen bomb has more explosive force than an → atomic bomb and can reach a TNT equivalent of up to 50 megatons (most powerful bomb tested until now), while the explosive force of an atomic bomb can usually be measured in kilotons (for an explanation of TNT equivalent → atomic bomb).

A hydrogen bomb requires high pressure and high temperature for ignition, so an atomic bomb is used to trigger the nuclear fusion. Some hydrogen bombs have a sheath of uranium in which nuclear fission reactions take place in a third stage of the detonation. The nuclear fission increases the yield of the bomb and the amount of → fallout produced (three-stage bomb).

Like atomic bombs, hydrogen bombs are also tested (→ nuclear weapons test).

Strictly speaking, the general term for such a weapon is "thermonuclear explosive"; a hydrogen bomb is a thermonuclear explosive dropped as a bomb from a plane. In everyday speech the terms are used as synonyms.

The even more general term "nuclear weapon" includes atomic bombs and hydrogen bombs.

Hydrogen explosion

→ Hydrogen is produced in the reactor as water is decomposed by radiation. In tanks with liquid → radioactive waste, hydrogen can be produced in the same way. Hydrogen is also used as turbine coolant.

If hydrogen accumulates in pipes or containers in a reactor or in a waste tank, contact with oxygen leads to an explosive mixture which is highly inflammable. The same dangerous situation arises if hydrogen leaks from the turbine cooling system.

IAEA

International Atomic Energy Agency. The IAEA is a UN organization which was founded in 1957 and has its headquarters in Vienna. Its aim is to encourage the use of nuclear energy worldwide. At the same time its objective is to prevent the further spreading of → nuclear weapons.

According to Article III of the Nuclear Non-Proliferation Treaty, the IAEA controls the activities of the member states to ensure that no civilian fissile material (→ uranium and → plutonium) is diverted for military purposes. Important states such as India and Israel have not signed this treaty yet. Moreover, the IAEA is confronted with the basic problem that all civilian nuclear power plants can also be used for military purposes - especially vulnerable in this respect are → uranium enrichment and reprocessing (→ reprocessing plant). The IAEA's aims are therefore inconsistent with one another.

In the area of civilian nuclear technology the IAEA carries out different activities, as for example support and counselling for national authorities, personnel training and drawing up guidelines for the safety of nuclear plants, which are, however, kept very general and only represent international minimum standards.

Incineration plant

Inflammable → radioactive waste that accumulates from the operation of a nuclear power plant (e.g. cleaning material and protective clothing that has been contaminated) is incinerated in the incineration plant to reduce its volume. For further storage the ashes are usually solidified, e.g. by mixing them with cement.

(In-)Core instrumentation

see Core instrumentation

Iodine-131

→ Isotope of iodine. Iodine-131 (I-131) is relatively short-lived (→ half-life of 8.07 days), but highly dangerous if it gets into the body. It accumulates in the thyroid gland and can cause thyroid cancer.

I-131 is released in large quantities in → core meltdown accidents as well as in nuclear weapons testing.

Ionizing radiation

Radiation which leads (directly or indirectly) to the ionization of matter, i.e. it removes → electrons from the orbit of an atom which then carries a positive electric charge. The most important types of ionizing radiation are: → alpha radiation, → beta radiation, → gamma radiation and → neutron radiation.

Isotope

Isotopes are different forms of a chemical element, depending on the different number of → neutrons in the nucleus. An element is characterized by a fixed number of → protons in the atomic nucleus - e.g. → hydrogen has one proton in the nucleus. Of the element hydrogen, three isotopes are known: "light", normal hydrogen, chemical symbol H, no neutrons; heavy hydrogen, deuterium (D), with one neutron in the nucleus; and extra heavy hydrogen, tritium (T) with two neutrons.

All isotopes of an element have the same chemical properties, but slightly different physical properties, a fact that is exploited e.g. in → uranium enrichment.

The term isotope is sometimes used colloquially to mean → radionuclide or just simply "radioactive material".

Isotope generator

An isotope generator contains a radioactive material, e.g. → plutonium, which by decaying gives off heat. This heat is converted into electricity. Generators of this type are used for power supply in space aviation or in remote places on earth (e.g. in lighthouses). A release of the radioactive inventory can lead to a considerable hazard for human beings.

(In medicine, devices that contain a long-lived radioactive material which decays into a short-lived one are also called isotope generators. The short-lived material can be extracted from the isotope generator and used for medical applications.)

Light-water reactor, LWR

→ Reactor that is → moderated and cooled with "light water" (H2O); as opposed to → "heavy water" (D2O). In a light-water reactor the → reactor core is enclosed in a → reactor pressure vessel and a flow of water through the core absorbs the heat produced by the chain reaction.

The LWR is the most prevalent reactor type in nuclear power plants worldwide. There are two different construction types: → pressurized water reactors and → boiling water reactors.

Lighthouse generator

see Isotope generator

Main transformer

see Transformer

Maintenance inspection

Periodic shutdown of a nuclear power plant, in about yearly intervals, during which almost always a part of the → fuel bundles is exchanged and different → periodic inspections, maintenance work and repair work are carried out.

Work done during a maintenance inspection is of great importance for the safety of a nuclear power plant. Nevertheless, the trend in the past years has been to shorten maintenance inspection times as much as possible for economic reasons.

Moderator, moderation

Core fission produces high-energy ("fast-moving") → neutrons. In nearly all reactor types (→ reactor) which are in commercial use today the → chain reaction is sustained by slow-moving → neutrons - i.e. by newly released neutrons that have been slowed down (moderated). Thus the reactors can be controlled more easily.

The moderator acts as a neutron brake - the fast-moving neutrons transfer their energy to the atomic nuclei of the moderator in repeated collisions. The energy transfer works best if the nuclei of the moderator are light. Therefore normal ("light") water H2O is an excellent moderator; → heavy water D2O not quite so, but still very appropriate. In some reactor types carbon in the form of graphite is used as moderator.

Natural uranium

see Uranium

Neutron, neutron flux

A neutron is an electrically neutral elementary particle. Neutrons and → protons form the atomic nucleus. In a → nuclear chain reaction, free neutrons move around.

During operation of a reactor the number of neutrons in the → reactor core that have been produced by → nuclear fission and move around freely in the fuel and between the → fuel bundles is very high. The density of the neutron flux is measured in neutrons per square centimetre and second; it is proportional to the output of the reactor.

Neutrons are not only produced during the chain reaction in a reactor. There are materials that emit neutron radiation. These are heavy radionuclides which fission spontaneously and emit neutrons in the process (e.g. curium-244). Also a fraction of cosmic radiation is composed of neutrons. Neutron radiation is characterised by its exceptionally high toxicity for organisms. The exact degree of their hazardousness for organisms has been the subject of much scientific controversy over the past years.

Neutron radiation

see Neutron

Nuclear chain reaction, chain reaction

A chain reaction is basically any self-sustaining reaction. The term nuclear chain reaction (also chain reaction) refers to a fission chain reaction in nuclear technology.

In a nuclear chain reaction the nucleus of a → fissile material (the nucleus of a fissile → isotope of → uranium or → plutonium) takes on a → neutron, breaks into two or three fragments and sets free more neutrons which can then again trigger fissions of fissile nuclei and so on.

A chain reaction goes hand in hand with intensive neutron radiation and heat generation. In a → reactor a controlled chain reaction takes place during operation; in an → atomic bomb an uncontrolled chain reaction that grows rapidly and exponentially is started. Moreover, when dealing with fissile materials, especially in liquid form (solutions), a spontaneous chain reaction can occur. It does not necessarily lead to an explosion, but in any case the solution is heated up and an intense shower of → neutrons goes down in the surroundings.

Nuclear fission

see Nuclear chain reaction

Nuclear submarine

A submarine powered by a nuclear → reactor; in this case an especially compactly built → pressurized water reactor.

Nuclear submarines can carry missiles whose warheads contain → nuclear weapons (strategic nuclear submarines). Others are destined for use against enemy ships and submarines (hunter submarines).

Submarine reactors are exposed to extremely high levels of strain, in an agitated system in a very confined space. The treatment and final storage of spent reactors is complicated and expensive and has led to considerable problems, particularly in Russia.

Nuclear weapons test

Detonation of a nuclear weapon for testing purposes.
Nuclear weapons tests are mainly carried out for the development of new weapons types and for information on the effects of the weapon tested. Up to now about 2050 such tests have been carried out (incl. tests of → hydrogen bombs). Of these, about a quarter were atmospheric tests (over ground).

Particularly the atmospheric tests led to worldwide fallout and to a very high → contamination in the vicinity of the test sites where the rates of cancer and other diseases were elevated. This was to be avoided by underground testing. However, the explosion sometimes reaches the surface, which also leads to the release of radioactive materials into the atmosphere (so-called "venting").

Operation under load

Operating a nuclear power plant for power generation, includes start-up, shutdown and load variation.

Trial runs with → nuclear chain reaction at zero power and tests at low capacity do not count as operation under load.

Partial meltdown

see Core meltdown

Periodic inspections, in-service inspections

In-service inspections are carried out regularly in nuclear power plants as a precaution against failures during reactor operation. They are complemented by special inspections. The following test methods are used, among others: pressure tests, testing the reaction time of valves, non-destructive test methods to identify material flaws, as for instance x-ray, ultrasound or eddy-current tests.

In-service inspections are of great importance for the safe operation of a nuclear power plant. Nevertheless, the trend in the past years in many countries has been to reduce the extent of these inspections and to increase the intervals between the inspections in order to save costs.

Plutonium

Artificial element, nº 94 in the periodic table. Chemical symbol Pu. Plutonium is produced in the reactor by capturing → neutrons from uranium-238 (→ uranium). This "reactor plutonium" contains the → isotopes plutonium-238 to plutonium-242, with Pu-239 dominating with a share of typically at least 60%. All Pu-isotopes mentioned are → alpha emitters, with the exception of Pu-241, which emits → beta radiation.

Isotopes Pu-239 and Pu-241 are fissile through neutron bombardment and can sustain a chain reaction. Especially the long-lived Pu-239 is usable as → fuel for → reactors and for the construction of nuclear weapons. Reactor plutonium is suitable for weapons construction; in general, however, weapon plutonium with over 90% Pu-239, which is produced in special reactors, is used for these purposes.

Plutonium is highly toxic, especially if inhaled.

Plutonium extraction

In → reprocessing plants, plutonium, among other materials, is isolated from the spent → fuel bundles. The stage of the reprocessing process in which this is done is called plutonium extraction.

Poisoning system

One of the safety systems in → boiling water reactors. Under certain conditions, the → reactor can be shut down and kept subcritical, i.e. the → chain reaction can be stopped, independently of the → control rods, by the injection of → boric acid.

Power supply

see Emergency power supply

Pressure control valve

Part of a safety system in → boiling water reactors, they are to guarantee the limitation of the pressure level in case of defective heat removal and failure of the → safety relief valves.

Pressure relief valve

see Safety relief valve

Pressure vessel, reactor pressure vessel, pressure tank

Various pressure vessels form part of the → emergency cooling system in → reactors of the → RBMK type. The vessels contain water under pressure, which is automatically fed into the coolant loop of the reactor in case of a pressure loss, without the need for pumps. Pressure vessels are the counterpart of the hydraulic accumulators which form part of the emergency cooling system of pressurized water reactors.

Pressure vessels can only make a contribution to emergency cooling for a short time span. In case of failure of other parts of the emergency cooling system, a → core meltdown is inevitable despite working pressure vessels.

Pressurized water reactor, PWR

Reactor type (→ reactor), sub-type of the → light-water reactor. The PWR was originally designed for the propulsion of → nuclear submarines and is therefore compactly built, with a high power density. Today it is one of the main reactor types operated worldwide.

The water cooling the reactor is under such a high pressure in the PWR that it does not start to boil. This water circulates in the so-called → primary coolant and gives off its heat to the → secondary coolant which is connected to the turbine.

Due to the high power density, in case of a breakdown of the cooling system the stage of → core meltdown is reached faster in a PWR than in other reactor types.

Primary coolant (circuit, loop), primary system

In nuclear power plants with two coolant loops between → reactor and turbine (e.g. → PWR or → CANDU), the first loop between reactor and → steam generator is called primary coolant (circuit or loop); sometimes also called primary system. The coolant in the primary coolant is radioactive.

The primary loop of pressurized water reactors is usually composed of four, in some plants of two or three, parallel lines which are connected to the reactor pressure vessel. Each line is composed of a reactor coolant line and a reactor coolant pump and is connected to the so-called primary side of a → steam generator. The pressurizer - a tank for fine-control of the pressure - is connected to one of the lines by the surge line.

Various control, cleaning and safety systems, e.g. the → emergency cooling system, are also connected to the primary coolant.

Proton

A proton is an elementary particle with a positive electric charge. → Neutrons and protons form the atomic nucleus.

Radiation dose

see Dose

Radiation source

A radiation source usually contains a radioactive material like cobalt-60 or caesium-137 which emits high-energy → gamma radiation. There are also some radiation sources that emit neutrons (e.g. containing americium or beryllium). Such sources are used in medicine (radiotherapy), for food irradiation, for testing weld seams, for measuring density and humidity, and in research. Due to the high intensity of the radiation, people near the source are endangered in case of insufficient shielding.

Spent radiation sources are often not disposed of correctly, either out of ignorance or to save costs. This can also lead to people being exposed to high doses, especially if a sealed source is opened. A radiation source can end up in the scrap metal and inadvertently be recycled together with other scrap metal. The consequences can be radioactive discharge into the atmosphere and → contamination of the products made from the recycled metal.

Radiation sources that are not disposed of correctly or that are not watched over properly can still be misused by terrorists for the construction of "dirty bombs" - these are devices with conventional explosives which serve to disperse radioactive material over a large area.

Radioactive contamination

see Contamination

Radioactive waste

Radioactive materials that are of no further use and have to be disposed of as waste.

Radioactive waste results from all areas of nuclear energy production (as well as from military nuclear programmes and the usage of radioactive materials in medicine, research and industry); the largest quantities are produced in uranium mining and the operation of reactors. Radioactivity is concentrated for the major part in the spent → fuel bundles from nuclear power plants. If these are reprocessed (→ reprocessing plant), their volume multiplies.

Radioactive waste shows the most diverse properties. It can be produced in liquid or solid form, it can be inflammable and it contains a number of radioactive materials with very diverse → half-lives. The amount of radioactive materials it contains also varies greatly. The radiation emitted by high level radioactive waste is so intense that without shielding a stay of only seconds in the immediate surroundings can be deadly. Intermediate and low level radioactive waste contains lower concentrations of radioactive materials.

Radioactive waste has to be treated (i.e. brought into a form that is as stable as possible) in order to reduce the risk of radioactive release. This can be achieved by embedding the waste in glass or concrete. Large amounts of waste are stored in liquid form worldwide as rapid solidification is too complicated and dangerous.

After treatment they are stored provisionally (in so-called temporary storage facilities). They are finally to be transported to a repository, i.e. a facility where they can be safely stored and sealed in for an indefinite time period.

The waste passes through various stages, but generally speaking the storage and treatment facilities are not all to be found on the same location so that transports become necessary. During these transports there is always a danger of accidents or terrorist attacks.

The preferred concept for ultimate waste disposal on a global scale at the moment are deep geological repositories, i.e. mines. However, until now final repositories have only been constructed for low and intermediate level radioactive waste, and with numerous problems (e.g. in the German final repositories Asse and Morsleben). The ultimate disposal of high level radioactive waste (this includes spent fuel bundles unless they have been reprocessed) is an unresolved problem on a worldwide scale.

Some waste types, particularly part of the waste produced from the application of radioactive materials in medicine, only contain → radionuclides with a very short → half-life. For these, and only for these, waste types a controlled storage during some decades can be sufficient - after that period of time the radioactive materials have decayed practically completely. Radioactive waste from nuclear energy production poses a threat for much longer periods of time. It contains radionuclides as for example plutonium-239 (→ plutonium) with a half-life of 24,204 years and iodine-129 (half-life 16,000,000 years). As a rule of thumb it can be said that after ten half-lives the original amount has been reduced to a thousandth part through decay.

High level radioactive waste with its high concentration of radioactive materials poses a unique threat which is not comparable to any other type of waste produced by human beings - and for tens of thousands of years. After some hundred thousand years the radiation hazard becomes relatively less important, although still considerable, while the hazards because of the chemical toxicity of the waste gain in importance. A dump of radioactive waste then approaches a heavy metal dump in terms of levels of toxicity. This chemical toxicity virtually lasts forever - the uranium isotope U-238 (→ uranium) which poses a relatively low radiation hazard but is chemically toxic like all uranium isotopes has a half-life of 4.47 thousand million years. Moreover, stable toxic heavy metals such as lead are to be found in a final repository, too.

Radionuclide

A nuclide is a material characterised by a fixed number of both → protons and → neutrons in the nucleus; i.e. a certain → isotope of an element. A radionuclide is a radioactive nuclide.

RBMK

Reaktor Bolshoi Moshnosty Kanalny, i.e. high-power channel-type reactor. Reactor type (→ reactor) developed in the Soviet Union with the dual objective of producing power and weapon-usable material. The RBMK uses normal, "light" water (H_2O) as coolant and graphite as → moderator. The → fuel bundles are not located in compact form in a → reactor pressure vessel, but in separate pressure tubes running through graphite blocks and cooled by water. As in a → pressurized water reactor, the steam that drives the turbine is produced in the reactor itself.

The reactors of the nuclear power plant at Chernobyl were of this type which poses serious safety concerns. Under certain conditions there is the risk of a sudden power surge; the graphite moderator is inflammable and the structure of the coolant loop with many pressure tubes exposed to a very intense neutron radiation leads to severe material problems.

Reactor

Facility in which a controlled → nuclear chain reaction on the basis of the nuclear fission of a → fissile material can be carried out. The centrepiece of the reactor is the reactor core, in which the chain reaction takes place. The reactor core comprises the → fuel bundles and the corresponding holding devices, the → control rods, → (in-)core instrumentation, → coolant and in nearly all reactor types also the → moderator to slow down the neutrons.

Mostly water is used as a coolant, but there are also gas-cooled reactors and those cooled by the metal → sodium. If water is the coolant it often serves as moderator, too. Another widespread moderator material is graphite.

Important reactor types with moderator ("thermal reactors") in commercial use today include → CANDU, → pressurized water reactor, → RBMK, → boiling water reactor and Advanced gas-cooled Reactor (AGR). Pressurized and boiling water reactors are → light-water reactors in which moderator and coolant are identical. The core of a modern pressurized water reactor contains about 200 fuel bundles with around 100 tons of fuel.

The most important reactor type without moderator is the → fast breeder reactor.

Apart from power-generating reactors (in nuclear power plants), reactors are used for marine propulsion (→ nuclear submarine), for research purposes and for the production of radioactive materials for medicine, research and industry. Nuclear power plant reactors are also sometimes used to provide district heating.

The term reactor is also used in chemistry where it designates vessels which contain chemical reactions. Because of the different contexts the risk of mingling up the two meanings is quite low.

Reactor core

see Reactor

Reactor pressure vessel

Cylindrical steel vessel which encloses the → reactor core in → light-water reactors. During reactor operation, the steel is exposed to intense neutron radiation (→ neutrons) which embrittles the material; the vessel is also under high pressure. The safety systems can not limit the consequences of the bursting of the reactor pressure vessel - this event inevitably leads to a severe accident with → core meltdown.

Reactor protection system, reactor safety system

System to control safety measures. With the help of sensors, the reactor protection system constantly controls those key values of a → reactor that are important for its safety, e.g. reactor capacity, pressure in the → primary coolant, fill level of the → steam generators. If one of the monitored values surpasses a certain limit, a protective action is triggered automatically, as for example a → reactor scram.

Disruptions in the reactor protection system can lead to situations where the operating staff is not able to determine the exact state of the reactor, and ultimately to severe accidents.

Reactor scram, scram system

Also emergency scram system. In a reactor scram the → control rods are fully inserted into the → reactor core in a matter of seconds. This brings the → nuclear chain reaction to a halt. The reactor scram has to be possible from any position of the control rods and under any operating pressure. Its failure can lead to a severe accident.

In → PWR the → control rods fall down into the reactor core from above due to gravity; in → BWR they have to be inserted hydraulically from below.

A reactor scram is usually accompanied by a turbine trip and leads to a high strain on the → primary coolant.

Redundancy, redundant

All important safety systems are included more than once (redundantly) in nuclear power plants, in a larger number than is strictly necessary. In many countries at least two systems more than necessary are present - i.e. for instance four systems with 50% of the required capacity each, or three with 100% each.

Multiple failures with a common cause can affect all components of a redundant system and thus lead to a severe accident in spite of redundancy - as would be the case in a manufacturing error that occurs in a whole batch of pumps, valves etc., or in an attack against the reactor site that leads to large-scale destruction.

Relief valve

see Safety relief valve

Reprocessing plant, fuel reprocessing plant

In a reprocessing plant, the spent → fuel bundles are reduced to small pieces mechanically. The fuel is dissolved in nitric acid. In a complicated chemical process, → uranium and → plutonium are then separated from the other radioactive materials in the solution, which form the waste stream, and re-solidified. This kind of reprocessing does not have much in common with the principle of environmentally friendly recycling.

The separation is never 100% effective. The isolated uranium and plutonium are contaminated with other radioactive materials, and, vice versa, a part of these two materials remains in the waste stream. Reprocessing is highly susceptible to trouble as it is a chemical process with many separate stages in which highly radioactive materials are treated using inflammable and explosive solvents. Even during normal reactor operation large amounts of radioactive materials are released into the environment with the waste air and water. During reprocessing there is an even greater danger that fissile materials are diverged without authorisation, as no precise quantities can be given when dealing with these materials in dissolved form.

Moreover, large quantities of → radioactive waste are produced in reprocessing. The isolated uranium is hardly ever re-used as nuclear fuel to date, the plutonium only to some extent.

Reprocessing is a technology with two possible objectives: in the same plant, plutonium can be isolated for → fuel bundles or for → atomic bombs.

Safety containment

see Containment

Safety relief valve

The safety relief valves are the most important components for pressure control and pressure relief in the cooling circuit of the reactor. They blow steam from the → reactor pressure vessel into a water basin (hydraulic seal of the so-called condensate chamber), where the steam condenses. Pressure is thus reduced.

There are various sets of safety relief valves (high → redundancy). If there is an accident with pressure relief failure (i.e. if the valves do not open - for instance due to a manufacturing error that affects the whole batch), the high pressure in the reactor pressure vessel can prevent the injection of sufficient quantities of water by the → emergency cooling systems in time. If, on the other hand, the safety relief valves open and stay open erroneously, manual action, which is susceptible to trouble, is required to ensure the cooling of the reactor.

Safety valve

Pressure control valve that opens automatically once a certain pressure limit is reached. In → PWR, for instance, the pressurizer in the → primary coolant loop is fitted with safety valves; in → BWR the cooling circuit is fitted with safety relief valves.

Scram

see Reactor scram

Secondary coolant (loop, system)

In nuclear power plants with two coolant loops between → reactor and turbine (e.g. → PWR or → CANDU), the second loop, which is located between → steam generators and turbine, is called secondary coolant (loop).

Parallel to the set-up of the primary coolant, the secondary coolant in PWR is usually composed of four, in some plants of two or three, parallel lines. Each line is composed of a live steam pipe (from steam generator to turbine) and a feedwater pipe (from turbine to steam generator).

Various safety systems are connected to the secondary coolant loop, e.g. the live steam safety valves and the emergency feedwater system.

Sievert

see Dose

Sodium

Light-weight metal (belonging to the alkali metals) that is abundant in natural compounds. Due to its relatively low melting point (97.7ºC) and its good heat transfer properties it is used as coolant in → fast breeder reactors. This leads to safety problems, however, as sodium reacts violently with water and air (resulting in the hazard of fires and possibly also explosions). Moreover, liquid sodium is corrosive (→ corrosion).

Spoil, spoil pile

Spoil is the waste produced in mining. It is stored in the form of dumps. The spoil in uranium mining contains rests of → uranium that is not only radioactive but also a chemically toxic heavy metal, as are other radioactive materials like radium. Due to elution with rainfall, these materials can find their way into groundwater and rivers.

Steam explosion, fuel coolant interaction

Sudden flashing of a large amount of water into steam which occurs when water is very rapidly heated.

In a → light-water reactor a steam explosion can occur during a → core meltdown accident and can augment the effects of an accident.

Steam generator

In a → pressurized water reactor or a → CANDU, steam generators transmit the heat produced in the → reactor core and given off to the cooling water in the → primary coolant circuit to a second cooling circuit, the → secondary coolant. They are fed with water (feedwater) on the secondary side that converts into steam in the steam generators. This steam powers the turbines.

Hence, on the secondary side of a steam generator there is water as well as steam. The water level has to be exactly controlled by so-called level controllers which are important for a safe operation of the plant.

To guarantee an effective heat transfer, the hot primary cooling water passes through many small, thin-walled pipes (heating pipes). These heating pipes are a weak spot of → pressurized water reactors. A failure (leakage or breaking) in a heating pipe can lead to a → core meltdown accident with very high release as the → containment is bypassed in this case and has no retention effect.

Transformer

Transformers are used to increase or decrease the voltage of alternating current ("step up" or "step down").

The generator of a large power plant typically produces a voltage between 10 and 30 kV (kilovolts). It is convenient to step up the voltage during transport to the consumer, as with a higher voltage the power output stays constant, but less current flows through the lines. Therefore every power plant is equipped with a transformer that steps up the voltage of the alternating current generated to the voltage used in the long-distance transmission line (between 110 and 400 kV).

In the reverse case, when the reactor has been shut down, the important safety systems are supplied with power from the grid by the transformer (→ emergency power system).

The electrical facilities in a power plant usually include various transformers. The large power transformer which provides the connection to the grid is also called main transformer.

Tritium

Radioactive → isotope of → hydrogen. The tritium core is composed of one → proton and two → neutrons. Tritium is produced in the → reactor by nuclear fission and when normal hydrogen or deuterium capture neutrons.

Tritium combines with hydrogen to form the compound T2O which has the same chemical properties as normal ("light") water from which it is difficult to separate. Tritium can therefore not be safely retained in nuclear power plants.

Tritium emits a relatively low-energy ("soft") beta radiation.

Uranium

Radioactive heavy metal found in nature. Nº 92 in the periodic table of elements, chemical symbol U. Natural uranium is composed of the → isotopes uranium-238 (99.27%) and uranium-235 (0.72%) and traces of uranium-234.

Uranium-235 can be split by → neutron bombardment and can sustain a chain reaction, so it is suitable as nuclear fuel and for nuclear explosives. In some reactor types (→ reactor), natural uranium can be used as fuel. → Light-water reactors need uranium with a higher content of uranium-235 (typically 3-5%), i.e. which is enriched in uranium-235 (→ uranium enrichment).

Uranium with a content of more than 20% of the → isotope uranium-235 (→ uranium enrichment) is called highly enriched. Starting from a 20% content of uranium-235, the uranium is assumed to be weapons-usable. Generally speaking, uranium with a content of 85% or more of uranium-235 is used in weapons.

The uranium isotope uranium-233 is also fissionable. It does not occur naturally, but can be produced by the neutron absorption of thorium-232.
All uranium isotopes mentioned are → alpha emitters.

Uranium, enriched

see Uranium, Uranium enrichment

Uranium enrichment, uranium enrichment plant

In uranium enrichment, the content of the fissile → isotope uranium-235 in the → uranium is increased. For this purpose, the uranium is combined to the chemical compound → uranium hexafluoride, UF6, which is gaseous at relatively low temperatures. The slight difference in weight between uranium-235 and uranium-238 is exploited for enrichment.

The most extensively used method today is the gas centrifuge process in which the UF6 gas is inserted into rapidly rotating centrifuges. The centrifugal force causes a partial separation - in the outer part of the centrifuge the content of U-238 is higher, while the content of uranium-235 is higher in the middle, from where the enriched uranium can be extracted. The enrichment effect in a single centrifuge is minimal, so the uranium flow has to pass through a series of centrifuges to achieve an important effect.

Other enrichment methods are the once widely used gaseous diffusion and the jet nozzle process.

Every enrichment plant can produce low-enriched uranium for the → fuel bundles of reactors (typically 3-5% U-235) as well as highly enriched uranium for nuclear weapons (more than 20% U-235; uranium with a content of more than 85% of U-235 is particularly weapons-usable). The production of highly enriched uranium is considerably more complex (more partial stages).

Uranium hexafluoride

Chemical compound of → uranium which is used for → uranium enrichment. Uranium hexafluoride (UF_6) is volatile and sublimates at a temperature of only 56.5 ºC (i.e. at this temperature it passes from the solid to the gaseous state). It can therefore be converted relatively easily into the gaseous state which is needed for the enrichment.

If UF_6 comes in contact with water - even with air humidity - a chemical reaction leads to the formation of hydrofluoric acid (HF), one of the strongest respiratory toxins.

Uranium nitrate

In the → reprocessing of spent → fuel bundles, fuel solutions are used from which the uranium can be extracted in form of a uranium nitrate solution. Uranium nitrate can also be used in research.

Vital area

Radiation protection area in a nuclear plant, i.e. an area in which people can be exposed to higher doses of radiation by irradiation from an external radioactive source or by inhaling or ingesting radioactive materials.

In the German radiation protection code, for instance, the vital area is defined as follows: A person can be exposed to an effective dose of more than 6 mSv or an equivalent dose of more than 45 mSv for the eye lens or an equivalent dose of more than 150 mSv for skin, hands, forearms, feet and ankles per calendar year (→ dose). The values are based on an assumed duration of stay in the vital area of 40 hours a week 50 weeks a year.

Vital areas have to be clearly limited and marked as such.