FACTS AND FIGURES

Nuclear Glossary

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The following is a list of terms commonly used in discussion of nuclear energy.

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A

Actinide: An element with atomic number of 89 (actinium) to 103. Usually applied to those above uranium – 93 up (also called transuranics). Actinides are radioactive and typically have long half-lives. They are therefore significant in wastes arising from nuclear fission, e.g. used fuel. They are fissionable in a fast reactor. Minor actinides are americium, curium and neptunium.

Activation product: A radioactive isotope of an element (e.g. in the steel of a reactor core) which has been created by neutron bombardment.

Activity: The number of disintegrations per unit time inside a radioactive source. Expressed in becquerels.

ALARA: As Low As Reasonably Achievable, economic and social factors being taken into account. This is the optimisation principle of radiation protection.

Alpha particle: A positively-charged particle emitted from the nucleus of an atom during radioactive decay. Alpha particles are helium nuclei, with 2 protons and 2 neutrons.

Atom: A particle of matter which cannot be broken up by chemical means. Atoms have a nucleus consisting of positively-charged protons and uncharged neutrons of almost the same mass. The positive charges on the protons are balanced by a number of negatively-charged electrons in motion around the nucleus.

TOP

B

Background radiation: The naturally-occurring ionising radiation which every person is exposed to, arising from the Earth's crust (including radon) and from cosmic radiation.

Barn: see *Cross-section*.

Base load: That part of electricity demand which is continuous, and does not vary over a 24-hour period. Approximately equivalent to the minimum daily load.

Becquerel: The SI unit of intrinsic radioactivity in a material. One Bq indicates one disintegration per second and is thus the activity of a quantity of radioactive material which averages one decay per second. (In practice, GBq or TBq are the common units).

Beta particle: A particle emitted from an atom during radioactive decay. Beta particles are generally electrons (with negative charge) but may be positrons.

Biological shield: A mass of absorbing material (e.g. thick concrete walls) placed around a reactor or radioactive material to reduce the radiation (especially neutrons and gamma rays respectively) to a level safe for humans.

Boiling water reactor (BWR): A common type of light water reactor (LWR), where water is allowed to boil in the core thus generating steam directly in the reactor vessel. (cf. *PWR*)

Breed: To form fissile nuclei, usually as a result of neutron capture, possibly followed by radioactive decay.

Breeder reactor: see *Fast Breeder Reactor* and *Fast Neutron Reactor*.

Burn: The process of undergoing fission (analogous to burning a fossil fuel) or otherwise becoming denatured in the reactor core.

Burnable absorber, burnable poison: A neutron absorber included in the fuel which progressively disappears and compensates for the loss of reactivity as the fuel is consumed. Gadolinium is commonly used, and erbium may also be used.

Burnup: Measure of thermal energy released by nuclear fuel relative to its mass, typically Gigawatt days per tonne of fuel (GWd/t).

TOP

C

Calandria: (in a PHWR reactor) a cylindrical reactor vessel which contains the heavy water moderator. It is penetrated from end to end by hundreds of calandria tubes which accommodate the pressure tubes containing the fuel and coolant.

CANDU: CANadian Deuterium Uranium reactor, moderated and cooled by heavy water (except for the ACR design, which is cooled by light water). These are the most common PHWRs (cf. *Heavy water reactor*).

Centrifuge: A cylinder spinning at high speed to physically separate gas components of slightly different mass, e.g. uranium hexafluoride with U-235 and U-238 atoms.

Chain reaction: A reaction that stimulates its own repetition, in particular where the neutrons originating from nuclear fission cause an ongoing series of fission reactions.

Cladding: The metal tubes containing oxide fuel pellets (cf. *Zircaloy*).

Concentrate: See *Uranium oxide concentrate* (U_3O_8).

Control rods: Devices to absorb neutrons so that the chain reaction in a reactor core may be slowed or stopped by inserting them further, or accelerated by withdrawing them.

Conversion: Chemical process turning U_3O_8 into UF_6 preparatory to enrichment.

Conversion ratio: (in a nuclear reactor) the ratio of new fissile nuclei to fissioned nuclei. In a normal reactor this as around 0.6, at high neutron energy in a fast reactor it may exceed 1.0, due to more neutrons per fission, making it a net breeder. (Above about 0.1 MeV, i.e. fast neutron spectrum, the number of neutrons released per fission increases from around 2.5, and at 10 MeV it reaches about 4.)

Coolant: The liquid or gas used to transfer heat from the reactor core to the steam generators or directly to the turbines.

Core: The central part of a nuclear reactor containing the fuel elements and any moderator.

Critical mass: The smallest mass of fissile material that will support a self-sustaining chain reaction under specified conditions.

Criticality: Condition of being able to sustain a nuclear chain reaction.

Cross-section: see *Neutron cross-section*.

TOP

D

Decay: Disintegration of atomic nuclei resulting in the emission of alpha or beta particles (usually with gamma radiation). Also the exponential decrease in radioactivity of a material as nuclear disintegrations take place and more stable nuclei are formed.

Decommissioning: Permanent removal of a facility (e.g. reactor) from service, also the subsequent actions of safe storage, dismantling and making the site available for unrestricted use.

Deconversion: The chemical process of turning UF6 into uranium oxide. Typically depleted UF_6 may be processed for long-term storage in a more stable chemical form. HF is a by-product.

Delayed neutrons: Neutrons released by fission products up to several seconds after fission. These enable control of the fission in a nuclear reactor.

Depleted uranium: Uranium having less than the natural 0.7% U-235. As a by-product of enrichment in the fuel cycle it generally has 0.25-0.30% U-235, the rest being U-238. Can be blended

with highly-enriched uranium (e.g. from weapons) to make reactor fuel.

Deuterium: "Heavy hydrogen", a stable isotope having one proton and one neutron in the nucleus. It occurs in nature as 1 atom to 6500 atoms of normal hydrogen, (Hydrogen atoms contain one proton and no neutrons).

Disintegration: Natural change in the nucleus of a radioactive isotope as particles are emitted (usually with gamma rays), making it a different element.

Dose: The energy absorbed by tissue from ionising radiation. One gray is one joule per kg, but this is adjusted for the effect of different kinds of radiation, and thus the sievert is the unit of dose equivalent used in setting exposure standards.

TOP

E

Electron volt: 1.6×10^{-19} joules, the amount of kinetic energy gained by a single electron when it accelerates through an electrostatic potential difference of one volt.

Element: A chemical substance that cannot be divided into simpler substances by chemical means; atomic species with same number of protons (being the atomic number of the element).

Enriched uranium: Uranium in which the proportion of U-235 (to U-238) has been increased above the natural 0.7%. Reactor-grade uranium is usually enriched to about 3.5% U-235, weapons-grade uranium is more than 90% U-235.

Enrichment: Physical process of increasing the proportion of U-235 to U-238. See also *SWU*.

EPC contract: Engineering, procurement and construction contract, such as for a new reactor.

TOP

F

Fast breeder reactor (FBR): A fast neutron reactor (q.v.) configured to produce more fissile material than it consumes, using fertile material such as depleted uranium in a blanket around the core.

Fast neutron: Neutron released during fission, travelling at very high velocity (20,000 km/s) and having high energy (c 2 MeV).

Fast neutron reactor (FNR): A reactor with no moderator and hence utilising fast neutrons. It normally burns plutonium while producing fissile isotopes in fertile material such as depleted uranium (or thorium).

Fertile (of an isotope): Capable of becoming fissile, by capturing neutrons, possibly followed by radioactive decay; e.g. U-238, Pu-240.

Fissile (of an isotope): Capable of capturing a slow (thermal) neutron and undergoing nuclear fission, e.g. U-235, U-233, Pu-239.

Fission: The splitting of a heavy nucleus into two, accompanied by the release of a relatively large amount of energy and usually one or more neutrons. It may be spontaneous but usually is due to a nucleus absorbing a neutron and thus becoming unstable.

Fissionable (of an isotope): Capable of undergoing fission: If fissile, by slow neutrons; otherwise, by fast neutrons.

Fission products: 'Daughter' nuclei resulting either from the fission of heavy elements such as uranium, or the radioactive decay of those primary daughters. Usually highly radioactive.

Fossil fuel: A fuel based on carbon presumed to be originally from living matter, e.g. coal, oil, gas. Burned with oxygen to yield energy.

Fuel assembly: Structured collection of fuel rods or elements, the unit of fuel in a reactor.

Fuel fabrication: Making reactor fuel assemblies, usually from sintered UO_2 pellets which are inserted into zircalloy tubes, comprising the fuel rods or elements.

TOP

G

Gamma rays: High energy electro-magnetic radiation from the atomic nucleus, virtually identical to X-rays.

Genetic mutation: Sudden change in the chromosomal DNA of an individual gene. It may produce inherited changes in descendants. Mutation in some organisms can be made more frequent by irradiation (though this has never been demonstrated in humans).

Giga: One billion units (e.g. one gigawatt is 10^9 watts or one million kW).

Graphite: Crystalline carbon used in very pure form as a moderator, principally in gas-cooled reactors, but also in Soviet-designed RBMK reactors.

Gray (Gy): The SI unit of absorbed radiation dose, one joule per kilogram of tissue.

Greenhouse gases: Radiative gases in the Earth's atmosphere which absorb long-wave heat radiation from the Earth's surface and re-radiate it, thereby warming the Earth. Carbon dioxide, methane and water vapour are the main ones.

TOP

H

Half-life: The period required for half of the atoms of a particular radioactive isotope to decay and become an isotope of another element.

Heavy water: Water containing an elevated concentration of molecules with deuterium ("heavy hydrogen") atoms.

Heavy water reactor (HWR): A reactor which uses heavy water as its moderator, e.g. Canadian CANDU (q.v.) which is a pressurised HWR (PHWR).

High-level wastes (HLW): Extremely radioactive fission products and transuranic elements (usually other than plutonium) in used nuclear fuel. They may be separated by reprocessing the used fuel, or the spent fuel containing those isotopes may be regarded as high-level waste. HLW requires both shielding and cooling.

High-enriched uranium (HEU): Uranium enriched to 20% U-235 or more. (That in weapons is about 90% U-235.)

TOP

I

In situ leaching (ISL): The recovery by chemical leaching of minerals from porous orebodies without physical excavation. Also known as in situ recovery (ISR) or solution mining.

Intermediate-level waste (ILW): Radioactive waste which requires shielding to protect people nearby, but not cooling.

Ion: An atom or molecule that is electrically-charged because of loss or gain of electrons.

Ionising radiation: Radiation (including alpha particles) capable of breaking chemical bonds, thus causing ionisation of the matter through which it passes and damage to living tissue.

Irradiate: Subject material to ionising radiation. Irradiated reactor fuel and components have been subject to neutron irradiation and hence become radioactive themselves.

Isotope: An atomic form of an element having a particular number of neutrons. Different isotopes of an element have the same number of protons but different numbers of neutrons and hence different atomic masses, e.g. U-235, U-238. Some isotopes are unstable and decay (qv) to form isotopes of other elements.

TOP

L

Laser enrichment: Uranium enrichment using tuned laser beams to cause photo-dissociation of UF_6 to solid UF_5^+ so that the ionised UF_5 (with U-235) can be separated.

Light water: Ordinary water (H_2O) as distinct from heavy water.

Light water reactor (LWR): A common nuclear reactor cooled and usually moderated by ordinary water. It is s generic designation including BWR and PWR types.

Low-enriched uranium (LEU): Uranium enriched to less than 20% U-235. (That in power reactors is usually 3.5 - 5.0% U-235.)

Low-level wastes: Mildly radioactive material usually disposed of by incineration and burial.

Low-level waste (LLW): Radioactive waste which can be handled safely without shielding.

TOP

M

Megawatt (MW): A unit of power, one million or 10^6 watts. MWe refers to electric output from a generator, MWt to thermal output from a reactor or heat source (e.g. the gross heat output of a reactor itself, typically around three times the MWe figure).

Metal fuels: Fuels using natural uranium metal, as used in a gas-cooled reactor.

Micro: one millionth of a unit (e.g. microsievert is 10^{-6} Sv).

Milling: Process by which minerals are extracted from ore, usually at the mine site, to produce a mineral concentrate for sale, e.g. U_3O_8.

Mixed oxide fuel (MOX): Reactor fuel which consists of both uranium and plutonium oxides, usually about 5% Pu, which is the main fissile component.

Moderator: A material such as light or heavy water or graphite used in a reactor to slow down fast neutrons by collision with lighter nuclei so as to expedite further fission.

TOP

N

Natural uranium: Uranium with an isotopic composition as found in nature, containing 99.3% U-238, 0.7% U-235 and a trace of U-234. It can be used as fuel in heavy water-moderated or graphite-moderated reactors.

Neutron: An uncharged elementary particle found in the nucleus of every atom except hydrogen. Solitary mobile neutrons travelling at various speeds originate from fission reactions. Slow (thermal) neutrons can in turn readily cause fission in nuclei of "fissile" isotopes, e.g. U-235, Pu-239, U-233; and fast neutrons can cause fission in nuclei of "fertile" isotopes such as U-238, Pu-239. Sometimes atomic nuclei simply capture neutrons.

Neutron cross-section: An indication of the probability of an interaction between a particle and a target nucleus, expressed in barns (1 barn = 10^{-24} cm^2).

Nuclear reactor: A device in which a nuclear fission chain reaction occurs under controlled conditions so that the heat yield can be harnessed or the neutron beams utilised. All commercial reactors are thermal reactors, using a moderator to slow down the neutrons.

Nuclide: elemental matter made up of atoms with identical nuclei, therefore with the same atomic number and the same mass

number (equal to the sum of the number of protons and neutrons).

TOP

O

Oxide fuels: Enriched or natural uranium in the form of the oxide UO_2, used in many types of reactor.

Operation and Maintenance (O&M) costs: The operational costs of running a nuclear power plant excluding fuel and any capital costs.

TOP

P

Plutonium: A transuranic element, formed in a nuclear reactor by neutron capture. It has several isotopes, some of which are fissile and some of which undergo spontaneous fission, releasing neutrons. Weapons-grade plutonium is produced in special reactors to give >90% Pu-239, reactor-grade plutonium contains about 30% non-fissile isotopes. About one third of the energy in a light water reactor comes from the fission of Pu-239, and this is the main isotope of value recovered from reprocessing used fuel.

Pressurised water reactor (PWR): The most common type of light water reactor (LWR), it uses water at very high pressure in a primary circuit and steam is formed in a secondary circuit.

TOP

R

Radiation: The emission and propagation of energy by means of electromagnetic waves or particles. (cf. *Ionising radiation*)

Radioactivity: The spontaneous decay of an unstable atomic nucleus, giving rise to the emission of radiation.

Radionuclide: A radioactive isotope of an element.

Radiotoxicity: The adverse health effect of a radionuclide due to its radioactivity.

Radium: A radioactive decay product of uranium often found in uranium ore. It has several radioactive isotopes. Radium-226 decays to radon-222.

Radon (Rn): A heavy radioactive gas given off by rocks containing radium (or thorium). Rn-222 is the main isotope, from decay of radium-226.

Radon daughters: Short-lived decay products of radon-222 (Po-218, Pb-214, Bi-214, Po-214).

Reactor pressure vessel: The main steel vessel of a nuclear reactor containing the reactor fuel, moderator and coolant under pressure.

Repository: A permanent disposal place for radioactive wastes.

Reprocessing: Chemical treatment of used reactor fuel to separate uranium and plutonium and possibly transuranic elements from the small quantity of fission products, leaving a much reduced quantity of high-level waste. (cf. *Waste*).

TOP

S

Separative Work Unit (SWU): This is a complex unit which is a function of the amount of uranium processed and the degree to which it is enriched, i.e. the extent of increase in the concentration of the U-235 isotope relative to the remainder. The unit is strictly: Kilogram Separative Work Unit, and it measures the quantity of separative work (indicative of energy used in enrichment) when feed and product quantities are expressed in kilograms.

e.g., to produce one kilogram of uranium enriched to 3.5% U-235 requires 4.3 SWU if the plant is operated at a tails assay 0.30%, or 4.8 SWU if the tails assay is 0.25% (thereby requiring only 7.0 kg instead of 7.8 kg of natural U feed).

About 100-120,000 SWU is required to enrich the annual fuel loading for a typical 1000 MWe light water reactor. Enrichment costs are related to electrical energy used. The gaseous diffusion process consumes some 2400 kWh per SWU, while gas centrifuge plants require only about 60 kWh/SWU.

Sievert (Sv): Unit indicating the biological damage caused by radiation dose measured in Gray (q.v.). One Gray of beta or gamma radiation absorbed has 1 Sv of biological effect; 1 Gy of alpha radiation has 20 Sv effect and 1 Gy of neutrons has 10 Sv effect. (cf. *Dose*).

Spallation: the abrasion and removal of fragments of a target which is bombarded by protons in an accelerator. The fragments may be protons, neutrons or other light particles.

Spent fuel: Used fuel assemblies removed from a reactor after several years use and treated as waste. Often it is another term for used fuel.

Stable: Incapable of spontaneous radioactive decay.

Steam generator: Part of a pressurised water reactor (PWR), a heat exchanger where very hot water under high pressure makes steam in a secondary circuit to drive a turbine.

TOP

T

Tailings: Ground rock remaining after particular ore minerals (e.g. uranium oxides) are extracted.

Tails: Depleted uranium (cf. *Enriched uranium)*, with about 0.2 to 0.3% U-235.

Temperature coefficient of reactivity: The change in reactivity due to changed temperature in the fuel. A negative temperature coefficient means that the reactivity is diminished as the temperature rises, so as to reduce the rate of fission and hence reduce the temperature - a natural negative feedback. Fast reactors have a strong negative temperature coefficient which is the basis of automatic power regulation and even load-following.

Tera: One million million units (e.g. one TWh is 10^{12} watt-hours or one billion kWh).

Thermal reactor: A reactor in which the fission chain reaction is sustained primarily by slow neutrons, and hence requiring a moderator *(as distinct from Fast Neutron Reactor)*.

Transmutation: Changing atoms of one element into those of another by neutron bombardment, causing neutron capture and/or fission. In an ordinary reactor neutron capture is the main event, in a fast reactor fission is more common and therefore it is best for dealing with actinides. Fission product transmutation is by neutron capture.

Transuranic element: A very heavy element formed artificially by neutron capture and possibly subsequent beta decay(s). Has a higher atomic number than uranium (92). All are radioactive. Neptunium, plutonium, americium and curium are the best-known.

TOP

U

Uranium (U): A mildly radioactive element with two isotopes which are fissile (U-235 and U-233) and two which are fertile (U-238 and U-234). Uranium is the basic fuel of nuclear energy.

Uranium hexafluoride (UF_6): A compound of uranium which is a gas above 56°C and is thus a suitable form in which to enrich the uranium.

Uranium oxide concentrate (U_3O_8): The mixture of uranium oxides produced after milling uranium ore from a mine. Sometimes loosely called yellowcake. It is khaki in colour and is usually represented by the empirical formula U_3O_8. Uranium is normally sold in this form.

Used fuel: Fuel assemblies removed from a reactor after several years' use.

TOP

V

Vitrification: The incorporation of high-level wastes into borosilicate glass, to make up about 14% of it by mass. It is designed to immobilise radionuclides in an insoluble matrix ready for disposal.

Void coefficient of reactivity: The change in reactivity due to boiling of coolant or moderator in the actual core. A negative void coefficient means that the reactivity is diminished, and the

blanace of the chain reaction is affected so as to reducte the rate of fission and hence reduce the temperature - a natural negative feedback.

TOP

W

Waste:

High-level waste (HLW) is highly radioactive material arising from nuclear fission. It can be what is left over from reprocessing used fuel, though some countries regard spent fuel itself as HLW. It requires very careful handling, storage and disposal.

Intermediate-level waste (ILW) comprises a range of materials from reprocessing and decommissioning. It is sufficiently radioactive to require shielding and is disposed of in engineered facilities underground.

Low-level waste (LLW) is mildly radioactive material usually disposed of by incineration and burial.

TOP

Y

Yellowcake: Ammonium diuranate, the penultimate uranium compound in U_3O_8 production, but the form in which mine product was sold until about 1970. See also *Uranium oxide concentrate*.

TOP

Z

Zircaloy: Zirconium alloy used as a tube to contain uranium oxide fuel pellets in a fuel rod (part of a reactor fuel assembly).

TOP

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