Unit 3 Nuclear and Hydel Power Plant

Session Plan 1

**Recap: cooling tower**

1. Cooling tower is used to transfer waste heat to atmosphere.
2. cooling towers are mainly used in thermal power stations, and chemical plants

**Nuclear energy – structure of the atom**

<http://en.wikipedia.org/wiki/Nuclear_structure>

[http://encyclopedia2.thefreedictionary.com/Nuclear+structure](http://encyclopedia2.thefreedictionary.com/Nuclear%2Bstructure)

**Nuclear structure**

At the center of every atom lies a small, dense nucleus, which carries more than 99.97% of the atomic mass in less than 10-12 of its volume. The nucleus is a tightly bound system of protons and neutrons which is held together by strong forces that are not normally perceptible in nature because of their extremely short range. The small size, strong forces, and many particles in the nucleus result in a highly complex and unique quantal system that at present defies exact analysis. The study of the nucleus and the forces that hold it together constitute the field of nuclear structure physics

The protons of the nucleus, being positively charged, generate a spherically symmetric electric field in which the atomic electrons orbit. The cloud of negatively charged atomic electrons normally balances the positive nuclear charge, making the atom electrically neutral. The atomic number of protons is usually denoted by *Z* and the number of neutrons, which are electrically neutral, by *N*. The total number of protons and neutrons (or nucleons) is the mass number *A* = *Z* + *N*. Isotopes have the same atomic number, *Z*, and hence are forms of the same chemical element, having the same chemical properties, but they differ in neutron number; isotones have a common number of neutrons, *N*, and isobars have the same mass number,

Nuclei have masses less than the sum of the constituents, the missing mass Δ*M* being accounted for by the binding energy Δ*Mc*2 (where *c* is the speed of light), which holds the nuclear system together. The characteristic energy scale is in megaelectronvolts (1 MeV = 1.6 × 10-13 joule). The internuclear forces generate an attractive potential field which holds the nucleus together and in which the nucleons orbit in highly correlated patterns. The volume of nuclei increases approximately linearly with mass number *A*, and the radius is roughly *R* = 1.2 × 10-15 · *A*1/3 m.

#### Size, shape, and density distributions

A variety of sophisticated techniques have been developed for precise estimates of the nuclear charge distribution, including electron scattering, the study of muonic atoms, and the laser spectroscopy of hyperfine atomic structure. An overall picture of the nuclear charge distributions emerges. The nuclear charge density saturates in the interior and has a roughly constant value in all but the lightest nuclei. The nucleus has a diffuse skin which is of nearly constant thickness.

Many nuclei are found to have nonspherical shapes. Unlike the atom, which has a spherically symmetric Coulomb field generated by the nucleus, the nuclear field is composed of a complicated superposition of short-range interactions between nucleons, and the most stable nuclear shape is the one that minimizes the energy of the system. In general, it is not spherical, and the nuclear shape is most simply described by a multipole power series, the most important term of which is the nuclear quadrupole moment. A positive quadrupole moment reflects the elongation of nuclei into a prolate or football-like shape, while a negative value reflects an oblate shape like that of Earth.

**Chemical and nuclear reactions in nuclear plant**

<http://en.wikipedia.org/wiki/Nuclear_reaction_rate#Reaction_rates>

## Energy conservation

[Kinetic energy](http://en.wikipedia.org/wiki/Kinetic_energy) may be released during the course of a reaction ([exothermic reaction](http://en.wikipedia.org/wiki/Chemical_reaction#Exothermic_reactions)) or kinetic energy may have to be supplied for the reaction to take place ([endothermic reaction](http://en.wikipedia.org/wiki/Chemical_reaction#Endothermic_reactions)). This can be calculated by reference to a table of very accurate particle rest masses,[[4]](http://en.wikipedia.org/wiki/Nuclear_reaction_rate#cite_note-4) as follows: according to the reference tables, the 63Li nucleus has a [relative atomic mass](http://en.wikipedia.org/wiki/Relative_atomic_mass) of 6.015 [atomic mass units](http://en.wikipedia.org/wiki/Atomic_mass_unit) (abbreviated [u](http://en.wikipedia.org/wiki/U)), the deuterium has 2.014 u, and the helium-4 nucleus has 4.0026 u Thus:

* Total rest mass on left side = 6.015 + 2.014 = 8.029 u
* Total rest mass on right side = 2 × 4.0026 = 8.0052 u
* Missing rest mass = 8.029 – 8.0052 = 0.0238 atomic mass units.

In a nuclear reaction, the total [(relativistic) energy is conserved](http://en.wikipedia.org/wiki/Conservation_of_energy). The "missing" rest mass must therefore reappear as kinetic energy released in the reaction; its source is the nuclear [binding energy](http://en.wikipedia.org/wiki/Binding_energy). Using Einstein's [mass-energy equivalence](http://en.wikipedia.org/wiki/Mass-energy_equivalence) formula *E* = *mc*², the amount of energy released can be determined. We first need the energy equivalent of one [atomic mass unit](http://en.wikipedia.org/wiki/Atomic_mass_unit):

1 u *c²* = (1.66054 × 10−27 kg) × (2.99792 × 108 m/s)²

= 1.49242 × 10−10 kg (m/s)² = 1.49242 × 10−10 J ([Joule](http://en.wikipedia.org/wiki/Joule))

× (1 [MeV](http://en.wikipedia.org/wiki/MeV%22%20%5Co%20%22MeV) / 1.60218 × 10−13 J)

= 931.49 MeV,

so 1 u *c²* = 931.49 MeV.

Hence, the energy released is 0.0238 × 931 MeV = 22.4 [MeV](http://en.wikipedia.org/wiki/MeV).

**Expressed differently**: the mass is reduced by 0.3%, corresponding to 0.3% of 90 PJ/kg is 300 TJ/kg.

This is a large amount of energy for a nuclear reaction; the amount is so high because the binding energy per [nucleon](http://en.wikipedia.org/wiki/Nucleon) of the helium-4 nucleus is unusually high, because the He-4 nucleus is "[doubly magic](http://en.wikipedia.org/wiki/Magic_number_%28physics%29)". (The He-4 nucleus is unusually stable and tightly bound for the same reason that the helium atom is inert: each pair of protons and neutrons in He-4 occupies a filled 1s [nuclear orbital](http://en.wikipedia.org/wiki/Nuclear_orbital) in the same way that the pair of electrons in the helium atom occupy a filled 1s [electron orbital](http://en.wikipedia.org/wiki/Atomic_orbital)). Consequently, alpha particles appear frequently on the right hand side of nuclear reactions.

The energy released in a nuclear reaction can appear mainly in one of three ways:

* [Kinetic energy](http://en.wikipedia.org/wiki/Kinetic_energy) of the product particles
* Emission of very high energy [photons](http://en.wikipedia.org/wiki/Photon), called [gamma rays](http://en.wikipedia.org/wiki/Gamma_ray)
* Some energy may remain in the nucleus, as a [meta stable](http://en.wikipedia.org/wiki/Metastable) [energy level](http://en.wikipedia.org/wiki/Energy_level).

When the product nucleus is meta stable, this is indicated by placing an [asterisk](http://en.wikipedia.org/wiki/Asterisk) next to its atomic number. This energy is eventually released through [nuclear decay](http://en.wikipedia.org/wiki/Nuclear_decay).

A small amount of energy may also emerge in the form of [X-rays](http://en.wikipedia.org/wiki/X-ray). Generally, the product nucleus has a different atomic number, and thus the configuration of its [electron shells](http://en.wikipedia.org/wiki/Electron_shell) is wrong. As the electrons rearrange themselves and drop to lower energy levels, internal transition X-rays (X-rays with precisely defined [emission lines](http://en.wikipedia.org/wiki/Emission_line)) may be emitted.

**Conclusion & Summary:**

1. Energy released in nuclear reaction may be kinetic energy
2. one atomic mass unit is equal to 931 MeV

**Session Plan 2**

Recap: **Chemical and nuclear reactions in nuclear plant**

1. Kinetic energy is released during nuclear reaction
2. A.m.u. denotes Atomic mass unit

**Binding energy**

<http://en.wikipedia.org/wiki/Nuclear_binding_energy>

Nuclear binding energy is the energy required to split a [nucleus of an atom](http://en.wikipedia.org/wiki/Atomic_nucleus) into its component parts. The component parts are [neutrons](http://en.wikipedia.org/wiki/Neutrons) and [protons](http://en.wikipedia.org/wiki/Protons), which are collectively called [nucleons](http://en.wikipedia.org/wiki/Nucleon). The binding energy of nuclei is always a positive number, since all nuclei require net energy to separate them into individual protons and neutrons. Thus, the [mass](http://en.wikipedia.org/wiki/Mass) of an atom's nucleus is always less than the sum of the individual masses of the [constituent](http://en.wiktionary.org/wiki/constituent) protons and neutrons when separated. This notable difference is a measure of the nuclear binding energy, which is a result of forces that hold the nucleus together. Because these forces result in the removal of energy when the nucleus is formed, and this energy has mass, mass is removed from the total mass of the original particles, and the mass is missing in the resulting nucleus. This missing mass is known as the [mass defect](http://en.wikipedia.org/wiki/Mass_defect), and represents the energy released when the nucleus is formed.

The term nuclear binding energy may also refer to the energy balance in processes in which the nucleus splits into fragments composed of more than one nucleon, and in this case the binding energies for the fragments, as compared to the whole, may be either positive or negative, depending on where the parent nucleus and the daughter fragments fall on the nuclear binding energy curve. If new [binding energy](http://en.wikipedia.org/wiki/Binding_energy) is available when light nuclei fuse, or when heavy nuclei split, either of these processes result in releases of the binding energy.

**Chemical and nuclear reactions in nuclear plant**

<http://en.wikipedia.org/wiki/Nuclear_reaction_rate#Reaction_rates>

Nuclear reaction is semantically considered to be the process in which two [nuclei](http://en.wikipedia.org/wiki/Atomic_nucleus), or else a nucleus of an atom and a [subatomic particle](http://en.wikipedia.org/wiki/Subatomic_particle) (such as a proton, [neutron](http://en.wikipedia.org/wiki/Neutron), or high [energy](http://en.wikipedia.org/wiki/Energy) [electron](http://en.wikipedia.org/wiki/Electron)) from outside the atom, collide to produce one or more [nuclides](http://en.wikipedia.org/wiki/Nuclide) that are different from the nuclide(s) that began the process. Thus, a nuclear reaction must cause a transformation of at least one [nuclide](http://en.wikipedia.org/wiki/Nuclide) to another. If a nucleus interacts with another nucleus or particle and they then separate without changing the nature of any nuclide, the process is simply referred to as a type of nuclear [scattering](http://en.wikipedia.org/wiki/Scattering), rather than a nuclear reaction.

**Radio active decay and half life**

http://en.wikipedia.org/wiki/Half-life

Half-life (t½) is the amount of time required for a quantity to fall to half its value as measured at the beginning of the time period. While the term "half-life" can be used to describe any quantity which follows an [exponential decay](http://en.wikipedia.org/wiki/Exponential_decay), it is most often used within the context of [nuclear physics](http://en.wikipedia.org/wiki/Nuclear_physics) and [nuclear chemistry](http://en.wikipedia.org/wiki/Nuclear_chemistry)—that is, the time required, probabilistically, for half of the unstable, radioactive [atoms](http://en.wikipedia.org/wiki/Atom) in a sample to undergo [radioactive decay](http://en.wikipedia.org/wiki/Radioactive_decay).

Conclusion & Summary:

1. Nuclear reaction must cause a transformation of at least one [nuclide](http://en.wikipedia.org/wiki/Nuclide) to another
2. [Binding energy](http://en.wikipedia.org/wiki/Binding_energy) is available when light nuclei fuse

**Session Plan 3**

Recap: **Radioactive decay and half life**

1. Half-life (t½) is the amount of time required for a quantity to fall to half its value
2. half-life" can be used to describe any quantity which follows an [exponential decay](http://en.wikipedia.org/wiki/Exponential_decay)

**Nuclear fission, chain reaction**

<http://en.wikipedia.org/wiki/Nuclear_chain_reaction>

A nuclear chain reaction occurs when one [nuclear reaction](http://en.wikipedia.org/wiki/Nuclear_reaction) causes an average of one or more nuclear reactions, thus leading to a self-propagating series of these reactions. The specific nuclear reaction may be the fission of heavy isotopes (e.g. 235U). The nuclear chain reaction releases several million times more energy per reaction than any [chemical reaction](http://en.wikipedia.org/wiki/Chemical_reaction).



1. A uranium-235 atom absorbs a neutron, and fissions into two new atoms (fission fragments), releasing three new neutrons and some binding energy.
2. One of those neutrons is absorbed by an atom of uranium-238, and does not continue the reaction. Another neutron is simply lost and does not collide with anything, also not continuing the reaction. However one neutron does collide with an atom of uranium-235, which then fissions and releases two neutrons and some binding energy.
3. Both of those neutrons collide with uranium-235 atoms, each of which fission and release between one and three neutrons, and so on.

**neutron energy, neutron life cycle**

<http://en.wikipedia.org/wiki/Nuclear_reactor_physics>

In a nuclear reactor, the [neutron](http://en.wikipedia.org/wiki/Neutron) population at any instant is a function of the rate of neutron production (due to fission processes) and the rate of neutron losses (via non-fission absorption mechanisms and leakage from the system). When a reactor’s neutron population remains steady from one generation to the next (creating as many new neutrons as are lost), the fission chain reaction is self-sustaining and the reactor's condition is referred to as "critical". When the reactor’s neutron production exceeds losses, characterized by increasing power level, it is considered "supercritical", and; when losses dominate, it is considered "subcritical" and exhibits decreasing power.

The "[Six-factor formula](http://en.wikipedia.org/wiki/Six_factor_formula)" is the neutron life-cycle balance equation, which includes six separate factors, the product of which is equal to the ratio of the number of neutrons in any generation to that of the previous one; this parameter is called the effective multiplication factor (k), a.k.a. Keff. k = *L*fρ*L*th*f*ηЄ, where *L*f = "fast non-leakage factor"; ρ = "resonance escape probability"; *L*th = "thermal non-leakage factor"; *f* = "thermal fuel utilization factor"; η = "reproduction factor"; Є = "fast-fission factor".k = (Neutrons produced in one generation)/(Neutrons produced in the previous generation) When the reactor is critical, k = 1. When the reactor is subcritical, k < 1. When the reactor is supercritical, k > 1.

"[Reactivity](http://en.wikipedia.org/wiki/Nuclear_chain_reaction)" is an expression of the departure from criticality. δk = (k - 1)/k When the reactor is critical, δk = 0. When the reactor is subcritical, δk < 0. When the reactor is supercritical, δk > 0. Reactivity is also represented by the lowercase Greek letter rho (**ρ**). Reactivity is commonly expressed in decimals or percentages or pcm (per cent mille) of Δk/k. When reactivity ρ is expressed in units of delayed neutron fraction β, the unit is called the *dollar*.

Conclusion & Summary:

1. [neutron](http://en.wikipedia.org/wiki/Neutron) population at any instant is a function of the rate of neutron production
2. The "[Six-factor formula](http://en.wikipedia.org/wiki/Six_factor_formula)" is the neutron life-cycle balance equation

**Session Plan 4**

Recap: **Neutron energy, neutron life cycle**

1. If fission chain reaction is self-sustaining and the reactor's condition is referred to as" critical"
2. When the reactor’s neutron production exceeds losses, characterized by increasing power level, it is considered "supercritical"

**Fusion reaction, types of reactors**

<http://en.wikipedia.org/wiki/Fusion_power>

Fusion power is the [power](http://en.wikipedia.org/wiki/Power_%28physics%29) generated by [nuclear fusion](http://en.wikipedia.org/wiki/Nuclear_fusion) processes. In fusion reactions, two light [atomic nuclei](http://en.wikipedia.org/wiki/Atomic_nucleus) fuse to form a heavier nucleus (in contrast with [fission power](http://en.wikipedia.org/wiki/Fission_power)). In doing so they release a comparatively large amount of energy arising from the [binding energy](http://en.wikipedia.org/wiki/Binding_energy) due to the [strong nuclear force](http://en.wikipedia.org/wiki/Strong_nuclear_force) which is manifested as an increase in [temperature](http://en.wikipedia.org/wiki/Temperature) of the reactants.

The basic concept behind any fusion reaction is to bring two or more nuclei close enough so that the [residual strong force](http://en.wikipedia.org/wiki/Strong_interaction) (nuclear force) in their nuclei will pull them together into one larger nucleus. If two light nuclei fuse, they will generally form a single nucleus with a slightly smaller mass than the sum of their original masses (though this is not always the case). The difference in mass is released as energy according to [Albert Einstein](http://en.wikipedia.org/wiki/Albert_Einstein)'s [mass-energy equivalence](http://en.wikipedia.org/wiki/Mass-energy_equivalence) formula *E* = *mc*2. If the input nuclei are sufficiently massive, the resulting fusion product will be heavier than the sum of the reactants' original masses, in which case the reaction requires an external source of energy. The dividing line between "light" and "heavy" is [iron](http://en.wikipedia.org/wiki/Iron)-56. Above this atomic mass, energy will generally be released by [nuclear fission](http://en.wikipedia.org/wiki/Nuclear_fission) reactions; below it, by fusion.

Fusion between the nuclei is opposed by the repulsive positive electrical charge common to all nuclei due to [protons](http://en.wikipedia.org/wiki/Proton) in the nucleus. To overcome this [electrostatic force](http://en.wikipedia.org/wiki/Electrostatic_force), or "[Coulomb barrier](http://en.wikipedia.org/wiki/Coulomb_barrier)", the kinetic energy of the atoms must be increased. The easiest way to do this is to heat the atoms, which has the side effect of stripping the [electrons](http://en.wikipedia.org/wiki/Electron) from the atoms and leaving them as bare nuclei.

**Pressurized water reactor and Boiling water reactor**

<http://en.wikipedia.org/wiki/Pressurized-water_reactor>

<http://en.wikipedia.org/wiki/Boiling-Water_Reactor>

Pressurized water reactors (PWRs) constitute the large majority of all Western [nuclear power plants](http://en.wikipedia.org/wiki/Nuclear_power_plant) and are one of three types of [light water reactor](http://en.wikipedia.org/wiki/Light_water_reactor) (LWR), the other types being [boiling water reactors](http://en.wikipedia.org/wiki/Boiling_water_reactor) (BWRs) and [supercritical water reactors](http://en.wikipedia.org/wiki/Supercritical_water_reactor) (SCWRs). In a PWR, the primary [coolant](http://en.wikipedia.org/wiki/Nuclear_reactor_coolant) ([water](http://en.wikipedia.org/wiki/Water)) is pumped under high pressure to the reactor core where it is heated by the energy generated by the [fission](http://en.wikipedia.org/wiki/Nuclear_fission) of atoms. The heated water then flows to a [steam generator](http://en.wikipedia.org/wiki/Water-tube_boiler) where it transfers its thermal energy to a secondary system where steam is generated and flows to turbines which, in turn, spin an electric generator. In contrast to a boiling water reactor, pressure in the primary coolant loop prevents the water from boiling within the reactor. All LWRs use ordinary [water](http://en.wikipedia.org/wiki/Water) as both coolant and [neutron moderator](http://en.wikipedia.org/wiki/Neutron_moderator).

PWRs were originally designed to serve as [nuclear propulsion](http://en.wikipedia.org/wiki/Nuclear_propulsion) for [nuclear submarines](http://en.wikipedia.org/wiki/Nuclear_submarine) and were used in the original design of the second commercial power plant at [Shipping port Atomic Power Station](http://en.wikipedia.org/wiki/Shippingport_Atomic_Power_Station).



The BWR uses de mineralized water as a coolant and [neutron moderator](http://en.wikipedia.org/wiki/Neutron_moderator). Heat is produced by nuclear fission in the reactor core, and this causes the cooling water to boil, producing steam. The steam is directly used to drive a [turbine](http://en.wikipedia.org/wiki/Turbine), after which it is cooled in a [condenser](http://en.wikipedia.org/wiki/Condenser_%28heat_transfer%29) and converted back to liquid water. This water is then returned to the reactor core, completing the loop. The cooling water is maintained at about 75 [atm](http://en.wikipedia.org/wiki/Atmosphere_%28unit%29) (7.6 [MPa](http://en.wikipedia.org/wiki/Pascal_%28unit%29), 1000–1100 [psi](http://en.wikipedia.org/wiki/Pounds_per_square_inch)) so that it boils in the core at about 285 °C (550 °F). In comparison, there is no significant boiling allowed in a PWR ([Pressurized Water Reactor](http://en.wikipedia.org/wiki/Pressurized_Water_Reactor)) because of the high pressure maintained in its primary loop—approximately 158 atm (16 MPa, 2300 psi). The [core damage frequency](http://en.wikipedia.org/wiki/Core_damage_frequency) of the reactor was estimated to be between 10−4 and 10−7 (i.e., one core damage accident per every 10,000 to 10,000,000 reactor years)



Conclusion & Summary:

1. The BWR uses de mineralized water as a coolant and [neutron moderator](http://en.wikipedia.org/wiki/Neutron_moderator)
2. PWRs were originally designed to serve as [nuclear propulsion](http://en.wikipedia.org/wiki/Nuclear_propulsion) for [nuclear submarines](http://en.wikipedia.org/wiki/Nuclear_submarine)

**Session Plan 5**

Recap: **Pressurized water reactor and boiling water reactor**

1. The cooling water BWR is maintained at about 75 [atm](http://en.wikipedia.org/wiki/Atmosphere_%28unit%29)
2. All PWRs use ordinary [water](http://en.wikipedia.org/wiki/Water) as both coolant and [neutron moderator](http://en.wikipedia.org/wiki/Neutron_moderator).

**Waste disposal of nuclear waste from the plant**

<http://en.wikipedia.org/wiki/Radioactive_waste>

Radioactive wastes are [wastes](http://en.wikipedia.org/wiki/Waste) that contain [radioactive](http://en.wikipedia.org/wiki/Radioactive_decay) material. Radioactive wastes are usually [by-products](http://en.wikipedia.org/wiki/By-product) of [nuclear power](http://en.wikipedia.org/wiki/Nuclear_power) generation and other applications of [nuclear fission](http://en.wikipedia.org/wiki/Nuclear_fission) or [nuclear technology](http://en.wikipedia.org/wiki/Nuclear_technology), such as [research](http://en.wikipedia.org/wiki/Nuclear_physics) and [medicine](http://en.wikipedia.org/wiki/Nuclear_medicine). Radioactive waste is [hazardous](http://en.wikipedia.org/wiki/Radiobiology) to most forms of life and the environment, and is [regulated](http://en.wikipedia.org/wiki/Regulation) by government agencies in order to protect human health and the environment.

Radioactivity naturally decays over [time](http://en.wikipedia.org/wiki/Time), so radioactive waste has to be isolated and confined in appropriate disposal facilities for a sufficient period of time until it no longer poses a hazard. The period of time waste must be stored depends on the type of waste and radioactive isotopes. It can range from a few days for very short-lived isotopes to millions of years for spent nuclear fuel. Current major approaches to managing radioactive waste have been segregation and storage for short-lived waste, near-surface disposal for low and some intermediate level waste, and [deep burial](http://en.wikipedia.org/wiki/Deep_geological_repository) or [partioning / transmutation](http://en.wikipedia.org/wiki/Nuclear_transmutation) for the high-level waste.

Waste from the front end of the [nuclear fuel cycle](http://en.wikipedia.org/wiki/Nuclear_fuel_cycle) is usually alpha-emitting waste from the extraction of uranium. It often contains radium and its decay products.

[Uranium dioxide](http://en.wikipedia.org/wiki/Uranium_dioxide) (UO2) concentrate from mining is not very radioactive - only a thousand or so times as radioactive as the [granite](http://en.wikipedia.org/wiki/Granite) used in buildings. It is refined from [yellowcake](http://en.wikipedia.org/wiki/Yellowcake) (U3O8), then converted to [uranium hexafluoride](http://en.wikipedia.org/wiki/Uranium_hexafluoride) gas (UF6). As a gas, it undergoes [enrichment](http://en.wikipedia.org/wiki/Enriched_uranium) to increase the [U-235](http://en.wikipedia.org/wiki/Uranium-235) content from 0.7% to about 4.4% (LEU). It is then turned into a hard [ceramic](http://en.wikipedia.org/wiki/Ceramic) oxide (UO2) for assembly as reactor fuel elements

The main by-product of enrichment is [depleted uranium](http://en.wikipedia.org/wiki/Depleted_uranium) (DU), principally the [U-238](http://en.wikipedia.org/wiki/Uranium-238) isotope, with a U-235 content of ~0.3%. It is stored, either as UF6 or as U3O8. Some is used in applications where its extremely high density makes it valuable such as [anti-tank](http://en.wikipedia.org/wiki/Anti-tank) [shells](http://en.wikipedia.org/wiki/KE-penetrator), even sailboat [keels](http://en.wikipedia.org/wiki/Keel) on at least [one occasion](http://en.wikipedia.org/wiki/Pen_Duick). It is also used with plutonium for making [mixed oxide fuel](http://en.wikipedia.org/wiki/Mixed_oxide_fuel) (MOX) and to dilute, or [downblend](http://en.wikipedia.org/wiki/Enriched_uranium#Downblending), highly enriched uranium from weapons stockpiles which is now being redirected to become reactor fuel.

Safety of Nuclear power plant

<http://en.wikipedia.org/wiki/Nuclear_safety>

Nuclear safety and security covers the actions taken to prevent nuclear and radiation accidents or to limit their consequences. This covers [nuclear power plants](http://en.wikipedia.org/wiki/Nuclear_power_plants) as well as all other nuclear facilities, the transportation of nuclear materials, and the use and storage of nuclear materials for medical, power, industry, and military uses.

The nuclear power industry has improved the safety and performance of reactors, and has proposed new safer (but generally untested) reactor designs but there is no guarantee that the reactors will be designed, built and operated correctly.

Nuclear safety therefore covers at minimum: -

* Extraction, transportation, storage, processing, and disposal of fissionable materials
* Safety of nuclear power generators
* Control and safe management of nuclear weapons, nuclear material capable of use as a weapon, and other radioactive materials
* Safe handling, accountability and use in industrial, medical and research contexts
* Disposal of nuclear waste
* Limitations on exposure to radiation

Conclusion & Summary:

1. The main by-product of enrichment is [depleted uranium](http://en.wikipedia.org/wiki/Depleted_uranium) (DU)
2. Nuclear safety and security covers the actions taken to prevent nuclear and radiation accidents

**Session Plan 6**

 Recap: Safety of Nuclear power plant

1. Nuclear safety includes safe disposal of nuclear waste
2. Safety of nuclear plant includes limitation on exposure to radiation

**Hydel power**

<http://en.wikipedia.org/wiki/Hydropower>

Hydropower or water power is [power](http://en.wikipedia.org/wiki/Power_%28physics%29) derived from the [energy](http://en.wikipedia.org/wiki/Energy) of falling water and running water, which may be harnessed for useful purposes. Since ancient times, hydropower has been used for [irrigation](http://en.wikipedia.org/wiki/Irrigation) and the operation of various mechanical devices, such as [watermills](http://en.wikipedia.org/wiki/Watermill), [sawmills](http://en.wikipedia.org/wiki/Sawmill), [textile](http://en.wikipedia.org/wiki/Textile) mills, dock [cranes](http://en.wikipedia.org/wiki/Crane_%28machine%29), domestic [lifts](http://en.wikipedia.org/wiki/Elevator), power houses and [paint](http://en.wikipedia.org/wiki/Paint) making.

Hydropower is used primarily to generate [electricity](http://en.wikipedia.org/wiki/Electricity). Broad categories include:



A [conventional](http://en.wikipedia.org/wiki/Hydroelectricity#Generating_methods) dammed-hydro facility (hydroelectric dam) is the most common type of hydroelectric power generation.

* [Conventional hydroelectric](http://en.wikipedia.org/wiki/Hydroelectricity#Generating_methods), referring to hydroelectric dams.
* [Run-of-the-river hydroelectricity](http://en.wikipedia.org/wiki/Run-of-the-river_hydroelectricity), which captures the kinetic energy in rivers or streams, without the use of dams.
* [Small hydro](http://en.wikipedia.org/wiki/Small_hydro) projects are 10 megawatts or less and often have no artificial reservoirs.
* [Micro hydro](http://en.wikipedia.org/wiki/Micro_hydro) projects provide a few kilowatts to a few hundred kilowatts to isolated homes, villages, or small industries.
* [Pumped-storage hydroelectricity](http://en.wikipedia.org/wiki/Pumped-storage_hydroelectricity) stores water pumped during periods of low demand to be released for generation when demand is high.

Conclusion & Summary:

* 1. [Pumped-storage hydroelectricity](http://en.wikipedia.org/wiki/Pumped-storage_hydroelectricity) stores water pumped during periods of low demand to be released for generation when demand is high.
	2. [Run-of-the-river hydroelectricity](http://en.wikipedia.org/wiki/Run-of-the-river_hydroelectricity), which captures the kinetic energy in rivers or streams, without the use of dams

**Session Plan 7**

Recap: Hydel power plants

1. [Small hydro](http://en.wikipedia.org/wiki/Small_hydro) projects are 10 megawatts or less and often have no artificial reservoirs
2. [Micro hydro](http://en.wikipedia.org/wiki/Micro_hydro) projects provide a few kilowatts to a few hundred kilowatts to isolated homes, villages, or small industries

**Advantages of water power**

<http://en.wikipedia.org/wiki/Hydropower>

#### Flexibility

Hydro is a flexible source of electricity since plants can be ramped up and down very quickly to adapt to changing energy demands.[[1]](http://en.wikipedia.org/wiki/Hydroelectricity#cite_note-wi2012-1)

#### Low power costs

The major advantage of hydroelectricity is elimination of the cost of fuel. The cost of operating a hydroelectric plant is nearly immune to increases in the cost of [fossil fuels](http://en.wikipedia.org/wiki/Fossil_fuel) such as [oil](http://en.wikipedia.org/wiki/Petroleum), [natural gas](http://en.wikipedia.org/wiki/Natural_gas) or [coal](http://en.wikipedia.org/wiki/Coal), and no imports are needed

#### Suitability for industrial applications

While many hydroelectric projects supply public electricity networks, some are created to serve specific [industrial](http://en.wikipedia.org/wiki/Industry) enterprises

#### Reduced CO2 emissions

Since hydroelectric dams do not burn fossil fuels, they are claimed to not directly produce [carbon dioxide](http://en.wikipedia.org/wiki/Carbon_dioxide). While some carbon dioxide is produced during manufacture and construction of the project,

### Disadvantages

#### Ecosystem damage and loss of land



Hydroelectric power stations that use [dams](http://en.wikipedia.org/wiki/Dam) would submerge large areas of land due to the requirement of a [reservoir](http://en.wikipedia.org/wiki/Reservoir).

Large reservoirs required for the operation of hydroelectric power stations result in submersion of extensive areas upstream of the dams, destroying biologically rich and productive lowland and river valley forests, marshland and grasslands. The loss of land is often exacerbated by [habitat fragmentation](http://en.wikipedia.org/wiki/Habitat_fragmentation) of surrounding areas caused by the reservoir

#### Siltation and flow shortage

When water flows it has the ability to transport particles heavier than itself downstream. This has a negative effect on dams and subsequently their power stations, particularly those on rivers or within catchment areas with high siltation.

#### Methane emissions (from reservoirs)

Lower positive impacts are found in the tropical regions, as it has been noted that the reservoirs of power plants in tropical regions produce substantial amounts of [methane](http://en.wikipedia.org/wiki/Methane). This is due to plant material in flooded areas decaying in an [anaerobic](http://en.wikipedia.org/wiki/Hypoxia_%28environmental%29) environment, and forming methane, a [greenhouse gas](http://en.wikipedia.org/wiki/Greenhouse_gas).

Conclusion & Summary:

1. Advantages of water power includes flexibility and cheaper cost
2. Disadvantages of Hydel power includes ecosystem damage and loss of land

**Session Plan 8**

 Recap: **Advantages of water power**

1. Water power is cheaper
2. Hydro power production is free from carbon dioxide emission

**Hydraulic turbine -Selection of turbines,**

<http://www.ritchiewiki.com/wiki/index.php/Water_turbine>

* Based on working head of water – high head, medium and low head
* Based on specific speed
* Based on part load efficiency
* Based on type of water available
* Based on the action of water flowing
* Based on the direction of flow

**Governing of turbines**

<http://en.wikipedia.org/wiki/Steam_turbine_governing>

Steam turbine governing is the procedure of controlling the flow rate of steam into a [steam turbine](http://en.wikipedia.org/wiki/Steam_turbine) so as to maintain its speed of rotation as constant. The variation in load during the operation of a steam turbine can have a significant impact on its performance. In a practical situation the load frequently varies from the designed or economic load and thus there always exists a considerable deviation from the desired performance of the turbine. The primary objective in the steam turbine operation is to maintain a constant speed of rotation irrespective of the varying load. This can be achieved by means of [governing](http://en.wikipedia.org/wiki/Governor_%28device%29) in a steam turbine



Conclusion & Summary:

1. Governing of turbines is used to maintain the speed of the turbine
2. Throttle governing control the speed of the turbine by throttle adjustment

**Session Plan 9**

Recap: Governing of turbines

1. Governing of turbines includes controlling the speed of the turbine
2. Types of governing includes throttle and nozzle governing

**Performance of turbines**

<http://www.britannica.com/EBchecked/topic/609552/turbine/45689/Overall-performance-characteristics>

The performance of a steam turbine is conventionally measured in terms of its heat rate—i.e., the amount of heat that has to be supplied to the feedwater in order to produce a specified generator power output. In the United States the heat rate is given by the heat input in Btus per hour for each kilowatt-hour of electricity produced by the turbo generator assembly. The heat rate depends on the steam generator exit temperature and pressure, the condenser pressure, the efficiency of the turbine in converting the thermal energy of the steam into work, the mechanical and bearing losses, the exhaust loss due to the kinetic energy of the steam leaving the final turbine stage, and the generator losses. The lower the heat rate, the less the thermal energy required and the better the efficiency. At constant condenser pressure, the heat rate can be decreased by about 11 percent when going from steam generator exit conditions of 10,000 kilopascals gauge and 538 °C to 24,100 kilopascals gauge and 538 °C, with a subsequent reheat temperature of 538 °C. The higher pressure, however, necessitates costlier equipment to contain the steam and to maintain the same reliability. Part-load operation, with its attendant loss of efficiency, always leads to higher heat rates.

**Comparison of turbines**

<http://en.wikipedia.org/wiki/Water_turbine>

|  |  |
| --- | --- |
| Impulse turbine | Reaction turbine |
| Pressure drop occurs only in nozzle and not in moving blade | Pressure drop occurs in fixed and moving blades |
| Blades are of profile type | Blades are of aero foil type |
| Admission of steam is not all round  | Admission of steam all round |
| Much power cannot be developed | More power can be developed |
| Low efficiency | High efficiency |
| Requires less space for same power | Requires more space for same power |
| Blade manufacture is not difficult | Blade manufacture is difficult |

 Conclusion & Summary:

1. In Impulse turbine energy available at the inlet of the turbine is Kinetic energy
2. Aero foil type blades are used in reaction turbine