Nuclear power in the present and future

During the last century, nuclear power has been established as a reliable source of energy in the major industrialized countries. Nuclear power plants provide about 17 percent of the world's electricity. In the United States, nuclear power supplies about 15 percent of the electricity overall. Although no new plants are scheduled to be built in the United States, nuclear power is growing to be a popular producer of power. It has recently enjoyed a revival in attention and research due to the environmental concerns surrounding current conventional energy sources. Issues of regulation and safety are at the forefront of all discussions involving nuclear power. (Lillington) One of the major concerns is the radioactive waste that is produced during the fission of uranium. Uranium is an element that was integrated into the planet during the Earth's formation from the dust of shattered stars. It was discovered by Martin Heinrich Klaproth in 1789 and although Klaproth thought the compound he extracted was pure uranium, it was actually uranium dioxide. Today, uranium is obtained from uranium ores such as pitchblende, uraninite, carnotite, and autunite. It can also be found in phosphate rock, lignite (brown coal) and monazite sand. There three different types of isotopes that can be found: uranium-234, uranium-235 and uranium-238. All three isotopes are radioactive, but uranium-235 is the only fissionable isotope that can be used for nuclear power. (Gagnon) Uranium-235 makes up about 0. 7 percent of the uranium that can be found naturally. It can be used for both nuclear power production and for nuclear bomb production. Uranium-235 decays naturally by alpha radiation and undergoes spontaneous fission a small percentage of the time. But it is its ability to undergo induced fission that makes it a good compound for use in nuclear power. That means if a free neutron runs into a uranium-235 nucleus, the nucleus would absorb the neutron without hesitation, become unstable and split immediately. When the nucleus splits other atoms form and two or three new neutrons are thrown off. The two new atoms then emit gamma radiation as they settle into their new states. The probability of a uranium-235 atom capturing a neutron as it passes by is fairly high. In a reactor one neutron, ejected from each fission, causes another fission to occur. This process of capturing the neutron and splitting the nucleus happens in a matter of picoseconds. The energy released when a single atom splits is massive and gives off heat and gamma radiation. The two atoms that result from the fission later release beta radiation and gamma radiation of their own as well. 3. 204 x 10-11 joules of energy is released from the decay of one uranium-235 atom which may not seem like much, but there are a lot of uranium atoms in a pound of uranium. So many that a pound of highly enriched uranium can be used to power a nuclear submarine or nuclear aircraft carrier and is equal to about a million gallons of gasoline. (Ong) Enriched uranium contains 2-3 percent of uranium-235, this enrichment is sufficient for use in a civilian nuclear reactor. Highly enriched weapons-grade uranium is composed of 90 percent or more uranium-235. For a nuclear reactor you need mildly enriched uranium. This is typically formed into pellets, approximately the same diameter as a dime and an inch in length. These pellets are arranged into long rods, and then collected together into bundles. The bundles are submerged in water inside a pressure vessel, the water acting as a coolant. To prevent the uranium from overheating and melting control rods, made out of a material that absorbs neutrons, are inserted into the bundle. A mechanism attached to the rods, allowing the operators to raise and lower the control rods, controlling the rate of the nuclear reaction. When an operator wants the uranium core to produce more heat, the rods are raised out of the uranium bundle. If less heat is wanted the rods are lowered into the center of the uranium bundle. To shut the reactor down the rods can be lowered completely, this is done in the event an accident or to change the fuel. The uranium core is a high-energy heat source that is then used to turn water it to steam to turn a turbine. The turbine spins a generator, turning the original heat energy in to usable electricity. In some reactors the steam also goes through a secondary heat exchanger to convert more of the water to steam. The advantage to this design is that the radioactive water/steam never contacts the turbine. Carbon dioxide or liquid metal can also be used as the coolant fluid, which is in contact with the reactor core, allowing the core to be operated at higher temperatures. (Gonyeau) After about 18 months in a reactor, fission begins to slow down, and the uranium rods must be replaced. It takes about 2 months to remove the old rods and place in the new ones. The used-up uranium rods are stuck in containers which are placed in swimming-pool sized tanks of water. In these tanks, the old rods lose some of their radioactivity and begin to cool down. However, many nuclear power plants are now running into the problem of their water tanks getting full of the rods, and are in need of a permanent storage place. Many scientists have argued about a long term storage for our nuclear waste. Many think the waste should be placed in concrete containers and buried far beneath the Earth's surface. Others say that some of the waste should be loaded into rockets and shot at the sun. Some countries have already decided on their plans. Canada is currently looking at a plan to bury their radioactive waste underneath the Canadian Shield. The United States has a plan to bury their waste underground in Nevada where some nuclear experiments and tests have already been conducted. So far, continuing debates have prevented much of anything from being done about nuclear waste. Unfortunately, after buried underground, the nuclear waste can take millions of years to decay. (Perin 240-280) Because there is so much uranium-238, which makes up most of the fuel in a reactor core, another reaction can take place creating plutonium-239. Uranium-238 can react by capturing one of the neutrons which are flying about in the core of the reactor and become (indirectly) plutonium-239. Plutonium-239 is very much like uranium-235, in that it fissions when hit by a neutron and this also yields a lot of energy, in fact about one third of the overall energy yield comes from the " burning" of plutonium-239. Plutonium was first produced by scientists, Glenn Seaborg, Joseph Kennedy, Edward McMillan and Arthur Wohl, by bombarding an isotope of uranium with deuterons. (Gagnon) Traces of plutonium have also been found in uranium ores, where it is naturally produced by neutron irradiation. Sometimes a plutonium-239 atom simply captures a neutron without splitting, and it becomes plutonium-240, the longer the fuel stays in the reactor the more plutonium-240 is in it. This is significant because when the spent fuel is removed, the plutonium in it is not suitable for making weapons but can be recycled as fuel. Most countries are planning, or have already implemented, plutonium recycling schemes in thermal reactors, principally pressurized water reactors. Plutonium is normally recycled as mixed oxide fuel, which is both uranium dioxide and plutonium dioxide together. When the mixed oxide fuel is spent the plutonium itself may be recovered, but the isotopic quality of the plutonium is degraded. Since this is the area where the greatest unknowns and uncertainties lie, the issue of multiple recycle of plutonium in thermal reactors leaves scientists wondering how many times thermal mixed oxide fuel can actually be recycled. With the isotopic quality of the plutonium degrading after each recycle there comes a point where further recycle is not possible. The benefits of using uranium for nuclear power and recycling plutonium are inarguable but there are also risks involved in both processes. The principal risks come from the health effects of radiation. The subatomic particles that radiate travel at or near the velocity of light (186, 000 miles per second.) They can penetrate deep inside the human body where they damage biological cells causing various types of cancer and genetic diseases in offspring. (Cohen) Those risks are greatly reduced, however, by rules and regulations implemented by the Nuclear Regulatory Commission (NRC) since the release of radioactive material from the nuclear reactor core at Three Mile Island in 1979. They, along with the Department of Energy (DOE), are responsible for upholding the Environmental Protection Agency (EPA) radiation exposure standards through regulation of nuclear power reactors and many other uses of radiation. All domestic nuclear power plants must have emergency plans that protect the public from radiation exposure. In the event of a release, or potential release, of radioactive material into the environment the EPA determines at which exposure level actions to protect the public take place. Several other federal agencies respond to radiological emergencies like the Federal Emergency Management Agency, the DOE, the Department of Health and Human Services, and the Department of Agriculture. In addition, state and local governments have primary responsibility for protecting the public and environment in the case of a radiological emergency. An issue that supports nuclear power is the ever increasing carbon dioxide concentration in our atmosphere. Many scientists are worried that if we continue to burn coal as our main source of energy the concentration will overwhelm the ecosystem causing cataclysmic damage. This being said, nuclear energy is the only proven technology that can deliver base load electricity on a large scale, 24 hours a day, 7 days a week, regardless-of-the-weather, without producing carbon dioxide emissions. Nuclear power could also help develop a replacement for petroleum based transportation fuel in the United States. It is able to provide the heat and hydrogen gas necessary for the manufacture process of synthetic oil from coal. If nuclear heat and nuclear generated hydrogen was used to produce synthetic oil from coal, the yield of oil from coal would be much higher. (Baurac) Resulting in much less CO2 being released in the process. Today, the United States burns approximately one billion tons of coal per year in power plants. Using one billion tons of coal to produce synthetic oil, at 3 barrels of oil per ton, could replace about 65% of America's imported oil and reduce the United State's atmospheric carbon dioxide emissions by 30%. Gasoline made from coal would not reduce carbon dioxide tailpipe emissions, because coal would merely replace fossil oil that is already being used for transportation fuel but, it would decrease the initial carbon dioxide released from the process. There are several reasons why there are no firm plans to build new nuclear power reactors. First among these, in the short term, is that most regions of the United States at this time have excess base load generating capacity. One exception is California, by importing much of their base load electricity needs. In this way they also effectively discourage new production from the typical base load power sources, coal and nuclear. So in order for any new nuclear construction to be considered the excess capacity must be worked off. A longer-term reason why no nuclear power have been built is that the capital costs of building a new nuclear power plant have historically been high. There are also considerable financial costs and risks related to the long construction periods in the industry. The last completed nuclear reactor, Watts Bar-1, took 24 years to complete. There has also been a history of regulatory uncertainty, like the Shoreham plant on Long Island that was almost completed before it was decided that it would not be allowed to operate. All of the issues previously mentioned also negatively affect future nuclear construction. The nuclear power industry and its promoters are addressing each of these issues. Prospective builders now promise lower costs and regulatory processes are now specified and implemented early and consistently in the decision process. Financial risk, construction periods, waste disposal, and safety are now being handled in more direct and organized manners. Difficulties with public acceptance remain but are hard to gauge. The Energy Information Administration (EIA) in its Annual Energy Outlook 2003 (Hagen) projects in its reference case that no nuclear units will become operable between 2001 and 2025. This projection is a reference scenario that functions as a mid-term forecast under the current laws and regulations. The EIA also examined a scenario where the costs of nuclear construction were lowered to a level that some vendors say they will achieve after first of a kind engineering and financing difficulties are worked out. The Annual Energy Outlook's conclusion under this " advanced nuclear cost case" is that additional nuclear power capacity would come on line if cost targets are reached. Are the environmental concerns about current conventional energies enough to make a difference in the future of nuclear power? Considering most of the risks and weighing them against nuclear power's potential it is clear that the future of nuclear power is approaching sooner than anyone could have anticipated. In addition to being reliable, cost-effective and resource-efficient, nuclear power is a clean energy source that helps meet the increasing energy demands of today's technology-driven society. Works Cited Perin, Constance . Shouldering Risks: The Culture of Control in the Nuclear Power Industry. 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