

NUCLEAR POWER

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April 1st, 2022

Abstract

Much of conversations that take place on the east side of the CU Boulder campus are centered around what the next source of energy is going to be for mass scale economies. Most of these conversations are initiated and continued out of fear for what the future holds or curiosity towards how the problem is going to be solved, or in a lot of cases, both emotions. A famous saying is that if you do not learn from history you are doomed to repeat it. This notion has validity, but this paper aims to challenge the application of these principles to the subject of sustainable energy. Nuclear energy is a subject that has been tarnished by fear and for many reasons, wrongfully so. This paper aims to give proper context to educate the reader and other sides of this stigma to enlighten the reader. This paper should demonstrate the author's skill of fluently discussing a scientific subject along with recognizing large scale trends in scientific development.

Introduction

Energy is the driving force of the world's economy and is extracted through many methods. Unfortunately, many of these methods are either limited and/or damaging to the environment. Nuclear Energy is one such limited source of energy but is very potent in energy potential measured through energy density as uranium is 25,000 times more energy intensive than coal (2). Coal was the powerhouse for many economies in the 19th and 20th centuries so with this difference in energy potential it would seemingly be obvious to open as many nuclear plants as possible for energy production. This is the logic that most scientists and economists adopted in the late 20th century as production of nuclear plants took off in the 70's but then saw a sharp drop off as the 90's approached (9). The reason for this drop-off was due to fear over safety hazards, hazards that if violated would not only destroy lives in close proximity but damage lives in the proximity of several miles. However, with advancements in science comes advancements in safety and so the technology has re-emerged in several parts of the world (9). This trend does come with skepticism as many still fear the potential impacts of these technologies and so the ethical debate persists. Should countries and companies accept the safety risks of evidently dangerous technology for economical advancement? This paper aims to present both sides along with trends that will inform the reader such that they can decide for themselves.

Nuclear power is the potent energy source on earth and the reasoning for this can be understood from a molecular analysis of fission. Fission is the act of a free neutron contacting an atom in free space. In most nuclear fission cases, uranium is the free atom species so upon contact the isotope form of this is adjusted from 235 neutron to 236 neutron per uranium atom (2). The 236-isotope of uranium is extremely unstable and so it naturally splits into Barium (141 neutrons) and Krypton (92 neutrons) which means that 3 free neutrons are emitted (2). This as one would suppose would (and does) cause a chain reaction when additional uranium 235 isotopes are in the vicinity. A single atomic reaction releases about 200 MeV by itself (2). There is a 3:1 ratio of neutrons released to neutrons required meaning that this creates a running reaction as it is higher order. Combine these two facets of the reaction and the reasoning is clear

how this reaction produces so much energy such that it can be lethal if this reaction is not in a controlled environment.

PWR – Thermal Reactor

The environment in which these reactions are contained are referred to as nuclear plants. Nuclear plants most notably consist of nuclear reactors and equipment to obtain such generators. The first nuclear reactor was successfully constructed from the Manhattan project during world war 2 and referred to as a Magnox reactor. Overtime, innovation lead to generation 1 reactors of the 50's and 60's and generation 2 reactors during the 70's and 80's (2). Current operational reactors are under the classification of generation 2. The most common operational reactor used today for industrial purposes are Pressurized Water Reactors (PWR) (2). PWRs are a type of thermal reactor that is pictured below (Figure 01). The design of this reactor is similar to that of a heat engine in that water is heated and subjected to a turbine to generate energy.

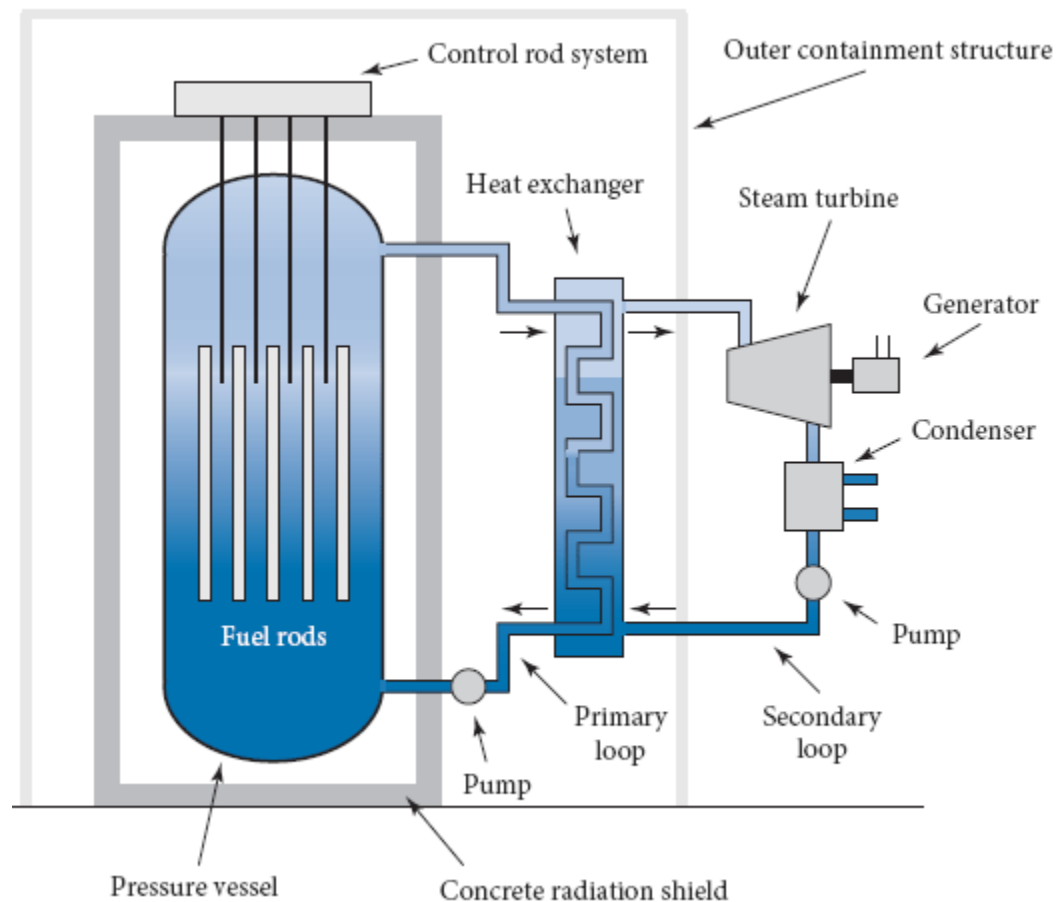


Figure 01: PWR Process Flow Diagram (2)

The water is heated by the uranium nuclear fission process mentioned previously in the form of cylinders labeled as the fuel rods pictured above. These fuel rods are composed of uranium pellets which are subject to nuclear fission provided ion projection (neutron travel) (2). This initiation is provided by the following water that these rods are subjected to. Water molecules do

not have the molecular properties to initiate these reactions but considering how sensitive this reaction is to initiation all it takes is one molecular deviation. Water has just that as about 1 in every 7,000 molecules is heavy (deuterium instead of hydrogen) enough to initiate this reaction (3). Referring to previous text, this reaction is very prone to run away so a method must be implemented to contain such a mechanism. Simply enough, water does just that even though it is also used as a reagent for the reaction (2). The properties of water allow for it to absorb emitted electrons from reaction. For PWRs, control rods are also inserted continuously between the fuel rods as another mechanism to absorb neutrons emitted (2). Water itself is prone to boiling due to these very exothermic reactions that it is containing but because these voids due to bubbling decrease the reactivity it is a naturally equilibrated process in this regard (2). One major safety concern of reactors and something that needs to be monitored is that neutron flow emitted from the fuel rods reduces the ductility of reactor shells and makes the material more brittle. As the material becomes more brittle it is more prone to cracks under given conditions and therefore an uncontrolled reaction. (2).

There are modifications of general thermal processes such as PWRs mentioned above. If the reactor core is designed so that fuel rods are bundled together in a more dense fashion than a fast reactor design is implemented (2). The primary differences between this reactor and the thermal reactor shown before is that a bowl structure is used to surround the reactor core (section of fuel rods) rather than a tubular structure (2). The bowl structure allows for a greater volume to be used which is necessary because the reaction will proceed faster with greater uranium density. The other major difference with a fast reactor is that Sodium is used instead of water to initiate and absorb the energy (2). This substance is chosen because it has a significantly higher boiling point that allows it to absorb greater amounts of energy without evaporating. This energy is transferred via a heat exchanger to a water-circulation system similar to that of the thermal process.

BWR – Boiling Water Reactor

The second most popular type of nuclear reactor used in industry is a boiling water reactor (BWR). BWRs are very similar to traditional PWRs but most notably the pressure is about half of the former (2). Water is fed through the fuel rods but is heated such that steam is produced and this steam is used to rotate the turbines rather than water for the PWRs (10). Additionally, the feed water is heated before entering the column containing as it is pumped through (10).

Progressions

One of the most important advancements in recent years was the development of smaller sized reactors. Most reactors are designed to produce 500 MW to 1 GW of electricity but recent research has produced plants for under the 300 MW threshold (11). This is especially important considering the nuclear industry is starting up from basically the ground up again after the abandonment in the 1990's because reactors are now able to be built in less time with less investment and still be used for significant production. Small modular reactors (SMR) also make the industry more flexible in terms of locations. This will prove greatly beneficial towards

developing countries in upcoming years as they are specifically in the market for such technologies for purposes such as residential electricity.

In addition to smaller reactors, nuclear reactor research has seen numerous modifications of past technologies that increase performance in a certain facet. These are referred to as Advanced nuclear power reactors. Examples of such reactors include Sodium-Cooled Fast Reactor which allow for higher-than usual temperatures along with lower-than usual pressures (8). Another variant is the Areva European Pressurized Water Reactor which can vary in output power from a quarter to its full 1.6 GWe (2).

Safety

The production and performance with these technologies is undeniable and is becoming that much more in demand due to recent environmental trends. It was stated earlier that this technology can be catastrophic if not managed correctly, but just how catastrophic? In April of 1986, 7 years after 3-mile Island occurred in the United States - an incident that was potentially catastrophic but was fortunately contained, a steam explosion occurred and blew open a nuclear reactor in Pripyat, Ukraine (9). This event was known as Chernobyl and it killed 31 people within a month from radiation burns and severe exposure (4). The total amount actually affected from this incident has been very difficult to tabulate. The reason is that radiation spread for several hundred miles around accident site and has been impacting people for decades after the incident. Many still consider this incident an on-going global catastrophe in which reports suggest that anywhere from 4,000 (WHO) to 985,000 (9)(5).

Chernobyl was the incident that put the world in fear of nuclear plants and shut down the vast majority of facilities over globe and halted future manufacturing of plants. It was not until 2015 that the general trend of nuclear plant manufacturing turned upwards (9). Interesting enough this was primarily due to China's newfound interest in nuclear technology (9). There is still widespread fear towards the technology and this was partly due to Fukushima's incident in 2011 of Japan in which catastrophic effects took place (9). These effects were weirdly not due to the radiation itself but the environmental impacts they had that included an earthquake and a tsunami. It is not just fear on behalf of the people that live in proximity of such plants but fear on behalf of the country. The area effected from Chernobyl, while open for tours, is still not habitual for health concerns as of 2022. Countries would essentially be risking their land by investing allowing these technologies to operate. 12 states in the US reportedly have active restrictions on construction of these plants (7).

Code of Ethics

The selected code of ethics is AIChE's Code of Ethics which were approved/revised in 2015.

Specific Statements that will applied to this subject and analyzed include:

- Hold Paramount the safety, health and welfare of the public and protect the environment in performance of their professional duties.
- Accept responsibility for their actions, seek and heed critical review of their work and offer objective criticism of the work of others.

- Issue Statements of present information only in an objective and truthful manner.
(1)

Assessing the statements in chronological order, it is paramount to any operation that the workers and management of plant value the wellbeing of the community in the surrounding area. While the environment reference does not apply in this context, the workers need to value the lives and safety of the general population as much as they do their jobs. The second statement was selected because for a company to uphold its safety standards it needs everybody from top to bottom to have the humility to admit when a mistake has been on their part. The worst thing a worker can do in a nuclear plant is make a critical error and not tell people about for the sake of their job/career. The potential consequences for letting an error are a lot more significant than one's (or a group's) reputation with respect to their career. The last statement was selected in concordance with second statement such that honesty is dependent on objectivity. Workers can intend to be honest but if they let their bias misconstrue what they are saying than mix-ups are likely to occur and therefore the potential for error is created.

Safety Resolution

There are 3 potential solutions that come to mind to mitigate the potential effects that nuclear energy could have on society. One notable method is isolating nuclear power plants from civilization with a distance in correlation to the amount of energy that particular plant produces. This would make travel more difficult for workers but would ensure, to a degree, that nearby residents could sleep well at night. Applying the love-one test, this would be a preferable method if a loved one were to be subjected to construction and operation nearby their place of residence. A scientifically-proven distance mandate would provide much-needed security.

The second proposal is already being implemented but perhaps can be implemented to a greater extent. It should be noted that the expected lifespan of a nuclear power plant is around 30 years and these plants are very expensive so companies will resist cutting operations short of the expected time (6). This is important because the nuclear industry should evolve towards more small-scale reactors such as the ones mentioned previously in this text. The larger the reactor, the more devastating the potential impact is. This is why SMRs have recently emerged and should continue to emerge. Applying the other-shoe test to this proposition, being the one affected by nuclear radiation would prompt immediate action to demand safety standards such as this to be implemented. The distance (first proposition) and size of the reactor are two of the biggest variables that indicate the extent of a potential incident.

The last proposition is in parallel to the global warming issue in pretention to the excessive CO₂ of circulating the atmosphere. There has been much research and many efforts towards eliminating the issue such as developing energy source methods such as nuclear energy but there has not been a whole lot research towards capturing radiation. This last proposition is directed towards large-scale research laboratories to initiate research towards the defense of radiation. If a solution other than evacuation can be implemented than this problem would not feared by many and this industry would thrive. Applying the front-page test to this proposition, there would expectedly be mass approval towards the idea of containing such harmful energy.

Many would support this idea but the problem is that many do not put in the time to solve this problem and so this issue persists. Of the 3 propositions presented, this last one seems to be the most useful as it is the one that has been considered amongst the nuclear industry the least. The other two, to an extent, are implemented but the research towards such contamination prevention would change the world.

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