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Impact of safety on the development of nuclear power plants in China

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***ABSTRACT*：** *This paper summarizes the two large-scale nuclear leakage accidents in modern times, briefly analyzes the working mode of Chernobyl and Fukushima nuclear power plants, and briefly describes the causes of the accidents. By analyzing the reasons of the accidents, the paper concludes the changes made by China's nuclear power plants for the two nuclear accidents, and the impact of nuclear accidents on the future development of China's nuclear power plants.*

KEYWORDS: *Chinese Situation, nuclear power plants, Fuel elements, Technology, NPP, Power.*

1. Literature Review : Chinese Situation

Until June 30, 2019, a total of 47 nuclear power plants have been operated in mainland China, which are distributed in 8 coastal provinces and 13 nuclear power bases in Zhejiang, Guangdong, Fujian, Jiangsu, Liaoning, Shandong, Guangxi and Hainan, with an installed capacity of 48.73 million kilowatts, and 11 units under construction with an installed capacity of about 11.34 million kilowatts.iIn 2018, a total of 7 nuclear power generating units in mainland China were qualified for commercial operation and began to operating. According to the statistical report of China Nuclear Energy Industry Association, in 2018, there were 44 commercial nuclear power units in the mainland of China, with a total installed capacity of 4464516 kilowatts, accounting for 2.35% of the total installed power capacity of the country; the annual nuclear power generation was 286.511 billion kW·h. Accounting for the total national power generation ,the annual average utilization hours of nuclear power equipment is 7499.22 hours, and the average utilization rate of equipment is 85.61%. Compared with coal-fired power generation, nuclear power generation reduces the combustion of standard coal by 88.2454 million tons, carbon dioxide emissions by 231.2029 million tons, sulfur dioxide emissions by 750.1 million tons, and nitrogen oxide emissions by 653000 tons.1

2. Introduction

In 19422, American scientist Fermi realized the nuclear chain for the first time in the graphite reactor under the grandstand of the University of Chicago stadium. After decades of continuous development, nuclear energy is recognized as an economical, clean, technologically advanced energy source with broad development prospects. According to the latest data released by the International Atomic Energy Agency in January 2011, there are currently 433 nuclear power units in operation worldwide. Power generation accounts for about 16% of the total global power generation; 65 nuclear power plants are under construction. In the current field of nuclear power generator which aimed to produce power, the world's main applications are relatively common or have good development prospects. There are five types of reactors: pressurized water reactor (PWR), boiling water reactor (BWR), high temperature gas-cooled reactor (HTGR) , fast neutron reactor (LMFBR)and heavy water reactor(HWR). Nuclear power in operation. Among the stations, PWR accounted for 67.2%, BWR accounted for 21.1%, HWR accounted for 6.3%, HTGR 2.8%,LMFBR 0.2%, and other types of reactors 2.43%.

3.Background

3.1 The Chernobyl accident

Chernobyl 4, 25 April 1986.The operator of the group planned to perform a test before the routine shutdown in order to confirm that the steam turbine could still continue to produce power during power failure and how long did the turbine could supply the routine. But it has been proved that the reactor is extremely unstable during the low efficiency mode. In preparation for the test in the early hours of April 26.The operator performed a series of operations, including shutting down automatic reactor-closing device. With the cooling water flow away. As a result, the output power of the reactor continues to rise. thereafter,The reactor was in unstable operation due to a series of operational errors.4

[1] China Academic Journal Electronic Public House 2019

[2] China Nuclear Journal 2018

[4] The Chernobyl Accident 200

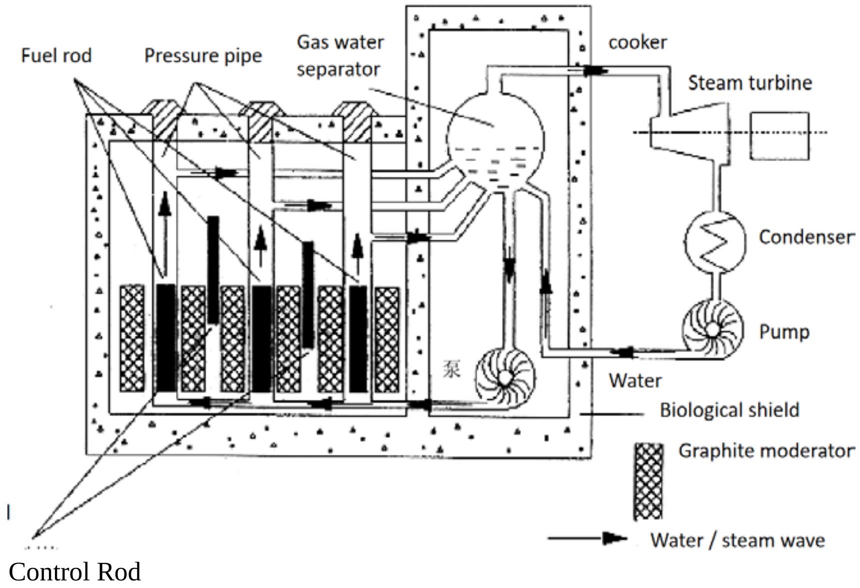

Figure.1

3.1 Basic structure:

3.1.1 Fuel elements

The micro enriched uranium oxide is sealed in a 3.65m long zirconium alloy tube to form fuel rod. A group of 18 fuel rods are arranged in a cylinder shape around the bracket to form a fuel assembly.

3.1.2 Pressure tubes

In the reactor, each fuel tube was placed in its own vertical pressure tube of 7 meters deep. Each channel is cooled separately by a coolant (pressurized water). The heated water boils in the tube and appears at about 290 ℃.

3.1.3Graphite moderator

A series of graphite blocks surround the pressure tube. The neutron released from the fission reaction moves too fast and its energy is too high to be absorbed by the nuclear fuel to produce fission reaction. The graphite moderator acts as a regulator to reduce the neutron speed, thus ensuring the continuous occurrence of chain reaction.

3.1.4 Control rods

Control rods are used to absorb neutrons to control the rate of fission. Control rods are distributed throughout the core. The control rod rod is automatically regulated by feedback from the detector in the core.For example ,the reactor power increases beyond the normal level,,the control rods can be put into the core to absorb the excess neutrons and slow down or stop the chain reaction, so that the nuclear fission reaction can be maintained at a controlling level

3.1.5 Cooling dose

Two separate water coolant circuits, each with four pumps, circulate water through the pressure tube to remove most of the heat from fission. There is also an emergency core cooling system that can be put into operation if the coolant circuit is interrupted

3.1.6 Steam separator

There are two steam generation separators in each circuit, in which the steam generated by the heated coolant from the core is sent to the turbine to drive the generator to produce electricity.Then the steam is condensed into water, which is used as circulating coolant to conduct heat conduction again.

3.2 The process of the accident:

A reactor used water as a coolant contains a certain amount of steam in its core. Water is a more effective coolant and neutron absorbing agent than steam, so the change of the proportion of vapor bubble or "gaps" in pressure tube will lead to the change of rate of nuclear fission. The ratio of these changes is called the "void coefficient.". The increase of steam will lead to the decrease of reactivity, which we call "negative void coefficient". The increase of steam will lead to the increase of reactivity, which we call "positive void coefficient".

The moderator and coolant used in most RMBK are "water". The excessive product of steam leads to the generation of many bubbles, forming a large number of "voids", occupying the space of moderator water in the core. However, the ability of steam to slow down neutrons is very poor, so many too fast neutrons can not slow down, so they can not collide with heavy atomic nuclei to produce fission , which results in a reduction in power, therefore has a "negative void coefficient," which is also the most basic safety feature of most reactors.

However, in Chernobyl RBMK reactor, graphite is the moderator.Water is the coolant, and it can also absorb neutrons. However, when the coolant water is converted into steam, on the one hand, water can not effectively absorb neutrons,it cannot reduce the number of neutrons and slow down the fission ; on the other hand, the coolant cannot transfer the heat generated by the reactor, making the reactor unable to cool down.However, the moderator graphite remains intact, and a large number of fast neutrons are slowed down to cause the chain reaction continue. The heat of nuclear reactor can not be derived, and the chain reaction is carried out normally without inhibition, so there is a "positive void coefficient".At the time of the Chernobyl accident. As power begins to increase, more steam is produced, which in turn leads to an increase in power. The additional heat generated by the increase in power increases the temperature in the cooling circuit and produces more steam. More steam means less cooling and less neutron absorption, resulting in a rapid increase in power to about 100 times the rated capacity of the reactor.

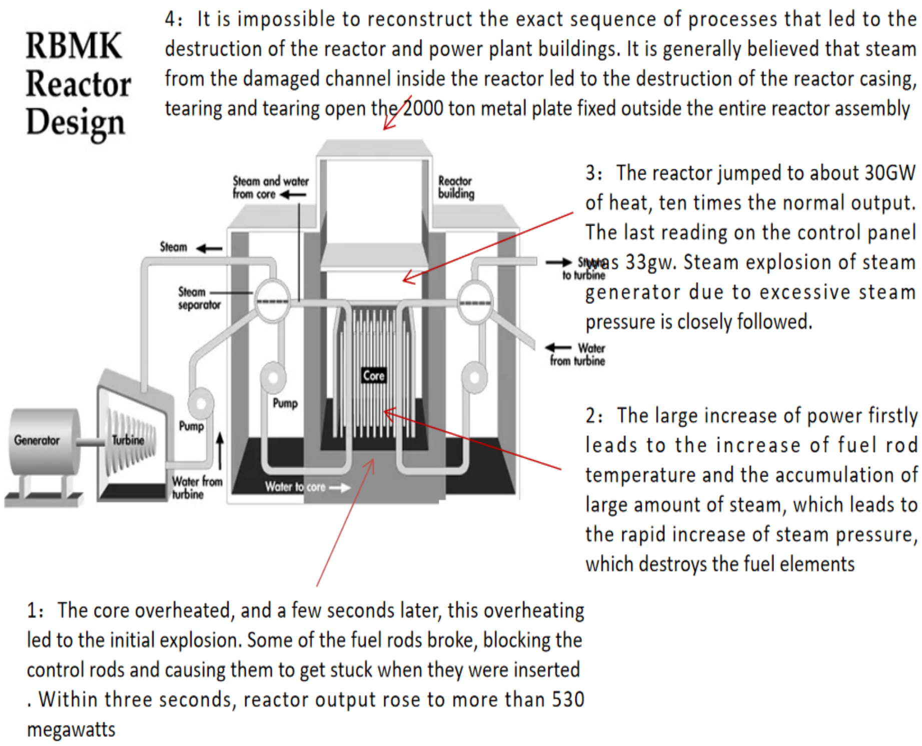

Figure 2.

3.3 According to these,the paper summary the 3 main reasons to cause accident

1.When reactor below 20% of full power. This makes the reactor easy to get out of control at low power.

2. The shutdown system is not appropriate. In fact, it can not correct the accident, but make the accident worse.

3. There is no effective protection to prevent nuclear leakage when the emergency system fails.

3.4 The Fukushima accident

On March 11, 2011, a strong earthquake with high magnitude occurred near the coast of Sendai, Japan.It was the largest earthquake recorded in Japan with a magnitude of 9.0.It severely damaged the Fukushima nuclear power plants of Tokyo Electric Power Company (TEPCO), which is located in the earthquake stricken area, and triggered a nuclear leakage. Since March 12, hydrogen explosion occurred successively in unit 1, unit 2 and unit 3 the nuclear power plant, and the top of the building (plant) where the reactor was exploded. On March 17, unit 4 nuclear power plant caught fire again, and then the side wall of the reactor building was also exploded . This series of accidents caused serious nuclear accident.

There is no big difference between the basic structure of Fukushima nuclear power plant and that of Chernobyl, but its reactor is a boiling water reactor, which is a more stable and mature reactor

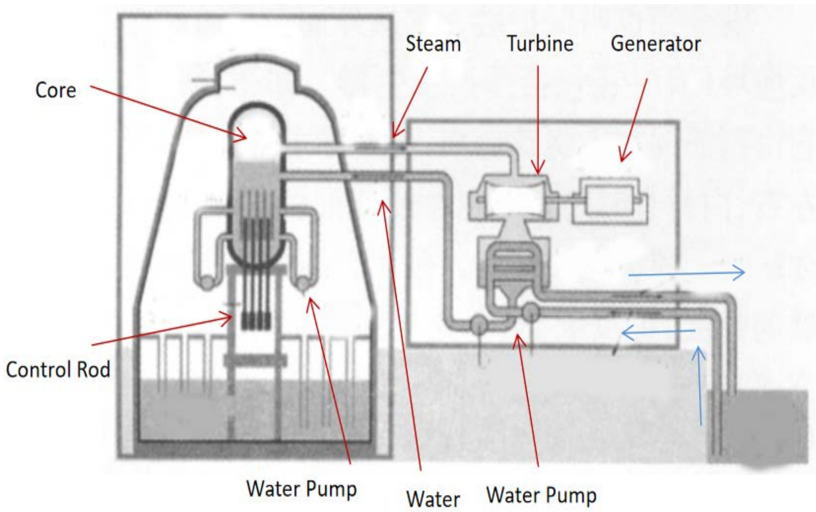

Figure 3.

3.5 The process of the accident:

3.5.1:The huge tsunami caused by the strong earthquake pushed the sea water to rush through the protective dike. After inundating the nuclear power plant, the power supply system of the unit was cut off, and the backup generator set in the basement of the turbine room was destroyed, so that the water pump relying on electric energy lost its power and could not be started

3.5.2:The water circulation of each loop system stops, the cooling system fails, and the steam in the pressure vessel can not be sent out for power generation as in normal working state. In particular, the control rod at the bottom can not be completely inserted into the fuel assembly due to power loss, which makes the nuclear reaction on the upper part of the fuel assembly continuously, and the reactor can not be completely shut down

3.5.3:The heat of the decay in reactor can not be dissipated in time. Part of the cooling water contains boron element used to reduce the pressure brought by the increasing steam in the pressure vessel.Part of the steam is led into the pressure suppression pool through the pressure relief valve. All of these make the cooling water level in the reactor drop rapidly, resulting in the formation of fuel above the water surface, and the core temperature and pressure are too high Burn and melt.

3.5.4:Radioactive materials such as cesium-137 escaped. The amount of hydrogen released from zirconium and the radioactive material are discharged to the outside with the steam through the valve on the suppression tank, which accumulates in the area between the containment and the building, resulting in excessive concentration and explosion under the action of oxygen at high temperature. The explosion overturned part of the roof or side walls of the plant, causing a nuclear leak

3.6 The Reason of Accident

1.The unpredictable Earthquake

In Japan, the country with high earthquake frequency and more than 70% of its nuclear power plants are built in high-risk areas, so earthquake and tsunami attack are considered in the design of nuclear power plants but most of the design standards are not high enough.The ability to resist the superposition of multiple natural disasters is not enough; they can only deal with the general level of earthquake and tsunami but not enough to withstand the damage of large earthquakes and tsunamis.

2.The Leak of Technology

Fukushima nuclear power plant belongs to the second generation reactor. This kind of boiling water reactor has the technical defects of "losing cooling water will lead to unbearable pressure" and "simply unable to bear the huge load caused by large-scale accident"

4. Conclusion Changes made by China

According to Chernobyl

4.1 The impact of this incident on China is that China has not used RBMK graphite reactor since then, and large-scale use of mature pressurized water reactor in China.

4.2 According to the incident, China has since greatly increased the thickness of the reactor protection wall, making it have the role of a Chernobyl "sarcophagus" to prevent the recurrence of a large-scale nuclear leak.

According to Fukushima

4.3 Distribution

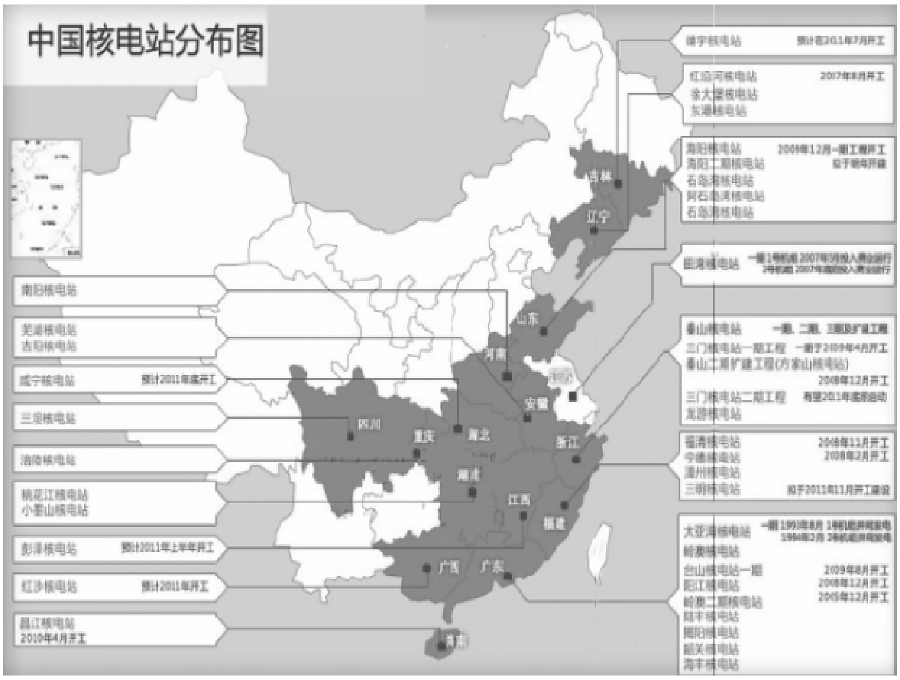

Figure 4.Chinese Distribution

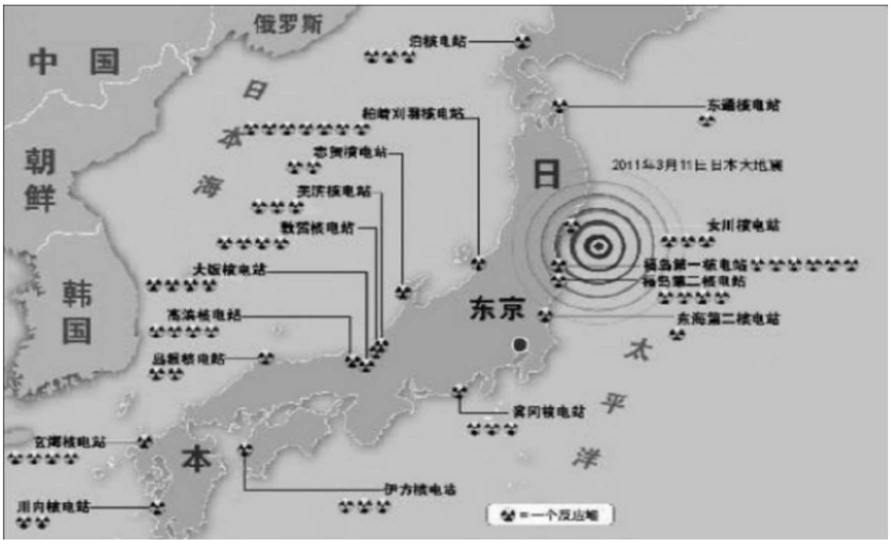

Figure 5.Japanese Distribution

It can be seen from the distribution that most of China's nuclear power plants are distributed along the coast of the sea, which has geographical similarity with Fukushima, but it is not located in the Pacific seismic zone like Fukushima. According to the conjecture of geographers, it is almost impossible for China's nuclear power plants to have natural disasters of Fukushima nature.

4.4 Improvement Made by Chinese NPP due to Fukushima

1.Seismic design

All systems, equipment and buildings related to the safety of nuclear power plant shall have the ability to resist safe shutdown earthquake, with an annual exceeding probability of 0.01%; the plant site must be far away from faults, especially the active faults with cracks or dislocations on the surface; the foundation of the plant shall be placed on the bedrock

2.Flood prevention requirements

The determination of reference flood level of coastal nuclear power station needs to consider external flood events, including the highest astronomical tide, possible maximum storm surge, tsunami, sea level rise, rainstorm flood, upstream dike break and wave influence. The annual exceeding probability is 0.1%. The elevation of the plant site of a nuclear power plant is generally higher than the reference flood level, that is, the so-called dry site. A wave wall should be set around the nuclear power plant site.

3.Nuclear power supply and emergency power supply

Each unit supplies power to the nuclear power plant through two auxiliary transformers from the main power network. At the same time, a dedicated standby external power line is also considered. In addition, each unit is equipped with two nuclear safety emergency diesel generators to provide emergency power for the nuclear power station and ensure the reliability of the emergency power supply. One additional diesel generator is set in each plant area to provide emergency power when the unit loses internal and external power supply.

4.Anti hydrogen explosion measures

Each unit is equipped with hydrogen concentration measuring device in different parts of the containment to monitor the hydrogen concentration; when the hydrogen concentration exceeds the standard, the mobile hydrogen recombination device is started to extract the air in the containment and ignite the hydrogen and oxygen

References

[1] Figure1.-CKNI Picture
[2] Figure2.-CNNC
[3] Figure3.-CNNC
[4] Figure4.5.-Effect of FUKUSHIMA on Chinese NPP 2011