Chapter 284

Nuclear technology in Brazil

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ABSTRACT
The electrical energy obtained through nuclear fission appeared in the 20th century, for military reasons, being used in the second world war. Years later, with a lot of bureaucracy, technology arrived in Brazil. The country has one of the largest sources of uranium in the world, an element used in the manufacture of fuel from nuclear plants. Currently, Brazil has two nuclear power plants and is moving towards the end of the third. In these plants, enriched uranium pellets are produced and few of them supply families for months.

Keywords: Nuclear Energy, Uranium, Technology, Brazil.

1 INTRODUCTION

It is inevitable to talk about nuclear energy and not mention the atom, and to express about the atom it is necessary to go back a long time ago, being more specific, in the 19th century, there were already speculations, but there was still no atomic model, after a century of research several models emerged, however, the currently accepted one is the atomic model of Schrödinger (1887-1961< in 1926 he developed the "Theory of quantum mechanics" where he dealt with the concept "Orbital". Orbital is the place between the nucleus and atomic element where through experiment and calculation it is possible to determine where the electron is.

In the meantime, another very important discovery for science as a whole was that of radioactivity, by the French researcher named Henri Becquerel (1852-1908), who studied phosphorescent elements and X-rays and ended up discovering that uranium emits a type of radiation that could print photographic plates, which for the time was a great advance, so much so that X-rays are of paramount importance for the area of medicine. After years, the couple Pierre and Marie Curie discovered that it was not just the uranium atom that had this incredible power. Among all research and applications, the most successful with atoms was fission, which enabled the creation of the bombs dropped on Hiroshima and Nagasaki and the creation of reactors powered by nuclear energy.

In Brazil, the first reports of nuclear technology were dated back to 1945, when an agreement was signed in exchange for certain sand containing thorium - an element used in the process. However, that proposal did not obtain the expected result, so in a secret operation, Brazil negotiated centrifuges developed by the Nazis, which would be used for the enrichment of uranium.

After a few years of conflict, in 1971 a contract was signed for the purchase of a reactor that, nowadays, is located in Angra dos Reis-RJ, called Angra 1. In 1975, construction of the second reactor began, completed after 25 years.

Brazil is a country that has several uranium mines – a key element in the production of nuclear fuel. Brazilian production of uranium concentrate began in the mid-1980s in Caldas, Minas Gerais, and for 13 years this was the only reserve used to supply fuel to Angra 1. With the advancement of geological studies, in 1995 other mines were discovered and the unit of INB (Indústrias Nucleares Brasileiras) in Caldas ended uranium production.

In Caetité, Bahia, there is a reserve that has 100,000 tons of ore, currently producing 400 tons per year of uranium concentrate, which is enough to supply the two active nuclear power plants in the country.

Bearing in mind that there are plans to build other nuclear power plants in Brazil, INB began its search for expanding the ore extraction territory in the country. In Caetité, a new uranium processing process was implemented and an underground mine was opened so that the best possible use of the ore could be obtained.

Currently, the country has the sixth largest uranium reserve in the world, located largely in Ceará. A nickel-white metal, slightly less resistant than steel, its main commercial application is the generation of electrical energy as fuel for nuclear power reactors. To do so, it goes through a series of stages and processes, including mining, enrichment, and the production of the fuel element, made up of uranium dioxide pellets. Two of these tablets have enough energy to power a house with four people for a month.

Nowadays, Brazil has two nuclear power plants, both located in Rio de Janeiro. Angra 1 and Angra 2 are responsible for 3% of the total electricity generation in the country. With a third plant under construction, the plan is that by 2030 the country will have 4 nuclear power plants.

2 NUCLEAR FUEL CYCLE

The process that turns uranium ore into nuclear fuel is called the Nuclear Fuel Cycle.

Figure 1 - Stages of the Nuclear Fuel Cycle

Source: INB – Indústrias Nucleares do Brasil

2.1 MINING

Uranium mining in Brazil is carried out by INB in Caetité – Bahia, where there is a resource of 99.1 thousand tons of ore. The uranium extracted from the mine undergoes primary and secondary crushing processes to reduce the size of its particles. After this procedure, the ore undergoes a leaching process, where it receives a sulfuric acid solution so that the uranium is removed from the rocks, resulting in a liquor known as sulfuric acid with uranium.

After going through several chemical and physical processes, this liquor is separated, generating a uranium concentrate, the yellowcake. This highly radioactive compound is stored in special iron drums, completely sealed, which go on to another stage of nuclear fuel: conversion.

2.2 CONVERSION

Dissolved and purified, the yellowcake compound is transformed into a solution called Uranium Hexafluoride (UF6), a “salt” that at low temperatures goes through the sublimation process. Already in gas form, the yellowcake goes to the enrichment phase. Currently, Brazil is unable to carry out this stage in the country, and therefore the process is carried out abroad.

The implementation of FNC – Conversão is in the preparation phase and will work at the INB unit, located in Resende. Still, on the implementation of the FNC, Indústrias Nucleares do Brasil state:

With the expansion of FCN - Enriquecimento's uranium enrichment capacity, the creation of the Conversion Factory will generate great savings for the company and an expected increase of up to 230 direct jobs and at least 350 indirect ones when the plant is in operation. full operation.

2.3 ENRICHMENT

Uranium dioxide is first converted to Uranium Hexafluoride and during this gaseous diffusion, the gas is passed through porous sieve-like plates as 235U is heavier than 238U, it passes more easily through the pores and this passage is repeated until the desired level of 235U is obtained.

This procedure is carried out using the ultracentrifugation process, which, in Brazil, was developed by the Technological Center of the Navy of São Paulo (CTMSP) together with the Institute of Energy and Nuclear Research (IPEN/CNEN). The term “ultra” centrifugation brings meaning to the fact that centrifuges operate at high tangential speeds to separate two elements of similar weight since the difference in mass between them is 1%.

The uranium that is retained in the “sieve” can be used in the lining of war tanks and the construction of weapon projectiles, since it is 2.5% heavier and more resistant than steel.

2.4 RECONVERSION

The return of gas to dust. Uranium Hexafluoride goes through the sublimation process again, changing from a gaseous state to a solid and yellow compound, Ammonium Uranyl Tricarbonate (TCAU), which, when heated, is mixed with hydrogen and water vapor.

This obtained powder, when stabilized, is used in another stage of the Nuclear Fuel Cycle: The production of pellets.

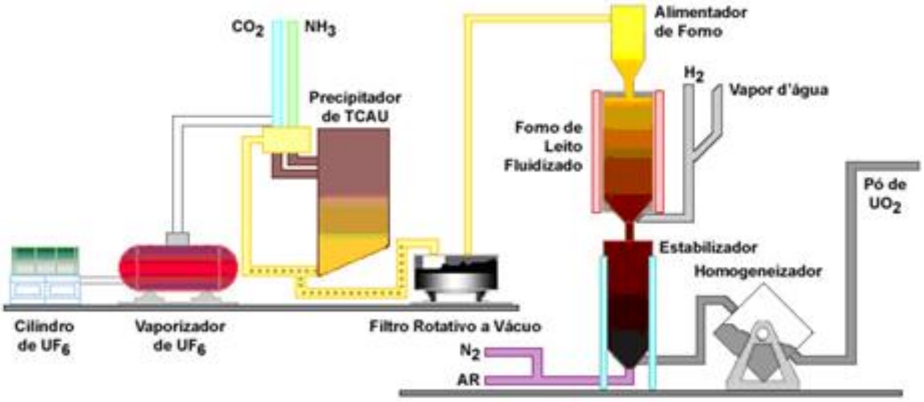
2.5 PILLS PRODUCTION

Enriched Uranium in powder form, also called Uranium Dioxide, is used in the production of pellets that have the shape of a small cylinder about 1 centimeter in diameter.

In the first stage of tablet production, UO6 goes through a mixing process with other uranium compounds, and then it is directed to a rotary press where green tablets are produced. A preheated oven at 1750ºC waits for these pellets to be sintered. During this heating process, the pellets gain rigidity and resistance to being submitted to a nuclear reactor.

Just two UO6 pellets are needed to supply electricity to a middle-class home with a family of four for a month.

Figure 2 - Tablet Production



Source: INB – Indústrias Nucleares do Brasil

Currently, only the Netherlands, England, France, Germany, the United States, Russia, Japan, China, and Brazil have authorization from the International Atomic Energy Agency to enrich uranium. For the time being, a large part of the uranium used in the manufacture of nuclear fuel for Brazil is enriched in France and England.

2.6 ASSEMBLY OF THE FUEL ELEMENT

Ready-made uranium pellets are stacked on Zircaloy rods, a super-resistant alloy.

Figure 3 - Zircaloy rods

Source: Jornal Beira Rio

These rods, together, are positioned with spacing and thus form the fuel element. Angra 1 and Angra 2 are supplied with two different types of fuel and both are produced by INB.

Incredible as it may seem, only one fuel element can remain in the reactor for three years, and after that period it is stored by the plants since it is a highly radioactive element that needs extra care.

This equipment will go inside the reactor, where the uranium pellets will come into contact with the water in that primary system, and it is in this system that nuclear fission takes place. The assembly of particles produced by INB changes according to the plant.

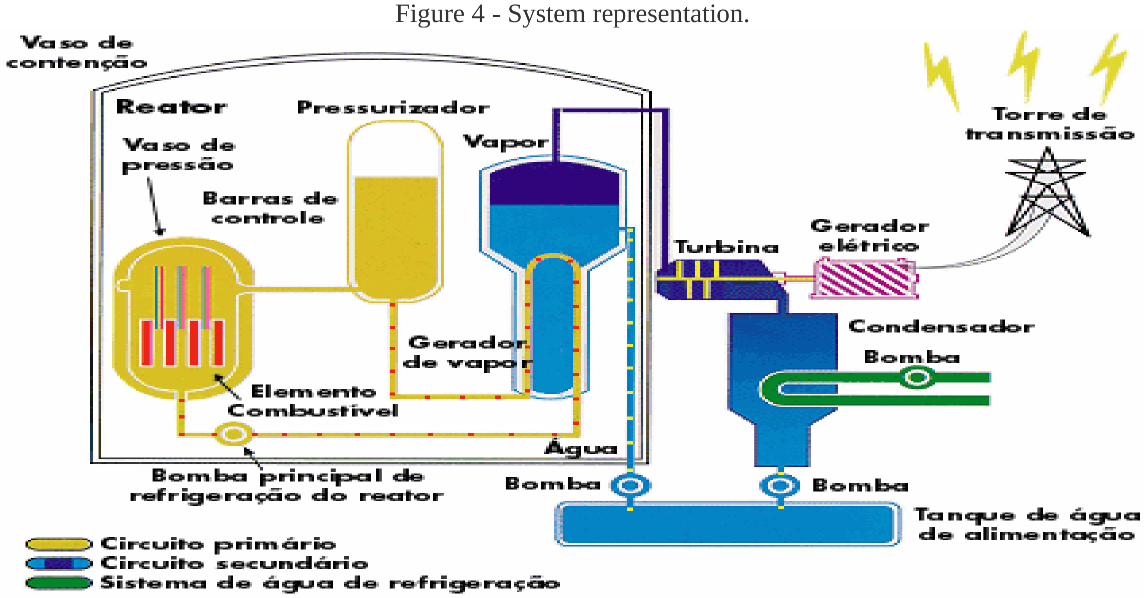
> The Angra 1 plant (Westinghouse technology) uses 121 fuel elements measuring 4 meters in length, each containing 235 rods rigidly positioned in a metallic structure, formed by 10 spacer grids, 1 protective grid, 20 guide tubes, and 1 instrumentation tube; and two nozzles, one lower and one upper. (INB - Nuclear Industries of Brazil)
> In the Angra 2 plant (Siemens technology) 193 fuel elements are used, 5 meters long, each with 236 rods rigidly positioned in a metallic structure, formed by 9 spacer grids, 1 protective grid, 20 guide tubes, and two nozzles, one lower and a superior. (INB - Nuclear Industries of Brazil)

3 NUCLEAR REACTOR OPERATION

The operation of the reactor takes place through a few steps until it reaches the distribution system for this energy, which are: reactor, pressurizer, steam generator, turbine, power generator, and condenser.

The image below represents the system that exists in Brazil, although it seems very simple, it is a very complex process because it is about radiation and nothing can go wrong.

Figure 4 - System representation.



Source: Eletrobras (Eletronuclear)

The reactor shell is made of steel and lead, which is used to contain radiation and this is due to its atomic weight. In addition to these layers, there is another 70 cm concrete wall. Although the risks are minimal, the structure must be well reinforced and well thought out, because if something goes wrong, this can help to avoid a bigger catastrophe. There are two types of energy emission, fusion and fission, however, what happens inside the Brazilian reactor is fission.

Nuclear fission happens when the nucleus of an atom, in this case, uranium, is hit by a neutron. This atom is divided into two more, thus generating energy. In this process other elements are formed that are also radioactive, these elements are called radioactive waste. It is a chain process and there must be a system that slows down this reaction. With that in mind, the control rods were developed, responsible for controlling the reaction. In the reactor it works as follows, after switching on the reaction starts and the water inside the system starts to heat up, reaching approximately 320°C, the interesting thing is that this water does not turn into steam because of the pressurizer which is at a high pressure very high, as the water is in direct contact with the radioactive elements it cannot come into contact with the rest of the process, so in the steam generator the heat exchange takes place, thus generating the steam that is directed to the turbine that is coupled to the generator of electrical energy, and thus the conversion of nuclear energy into electrical energy is carried out, to increase the time of use of the water, which is in contact with the fission process, it passes through a condenser and then returns to the system, in the In Brazil, sea water is used for condensation, it is worth mentioning that under no circumstances can this water come into contact with other systems that contain water, so that no type of contamination occurs.

After using the fuel element, the chemical elements formed from the fission must be stored, that is, the reactor is not the only place that has radioactive material, having to remain stored for thousands of years.

4 FINAL CONSIDERATIONS

Brazil currently has two nuclear power plants, Angra 1 and Angra 2, responsible for 3% of the country's total electricity generation. Angra 3 has been under construction for 35 years and is expected to be completed by 2026, as it is 62% complete, but the work has been frozen since 2019 due to the car wash operation. So far, the country's biggest source of electricity comes from hydroelectric plants.

The location chosen for the construction of the Plants was not random. They were established by the sea precisely because the reactors need to be cooled all the time, but this does not mean that they are in direct contact with the water.

Accidents caused in places like Chernobyl and Fukushima have no real chance of happening in Brazil. The type of reactor used in Angra 1 and Angra 2 is different from the one used in Chernobyl. The one used in the past when a big accident occurred used graphite to control the nuclear fission process, while current reactors use pressurized water.

The biggest aggravating factor of the accident in Chernobyl was the fire, which remained for more than five days, spreading radiation through the air for several kilometers. In Brazil, such an accident would not have happened, since the water would prevent the spread of fire, as happened with graffiti.

The Fukushima incident was because a seaquake followed by a tsunami shook the structures of the plant, compromising the reactor, and resulting in the leakage of radioactive material. As much as the plants are by the sea, Brazil does not have a history of events similar to those that occurred in Japan.

Studies are constantly carried out to analyze the area close to the plant. From seawater contamination tests to training with the population that lives in the vicinity of the plants. For example, simulations, so that people can protect themselves from a possible nuclear accident at any time.

Another possible accident that could happen at the plant, but with an irrelevant probability of occurrence, is the plane crash in the plant, compromising the structure of the plant and thus the reactor. Angra 1 and Angra 2 are located 4 kilometers from the air route that connects Rio de Janeiro to São Paulo. An accident of such proportions could be fatal for many people, but it is almost impossible to happen.

Currently, the biggest problem in the generation of electricity through nuclear fission is the radioactive waste generated by these plants. These wastes generated are highly radioactive and require special treatment to be disposed of, which is why they are kept close to the reactors in pools. This radioactive waste is stored inside drums to contain the radiation. This would be a temporary solution, but it ended up remaining until the present day since there are still no solutions to dispose of this type of waste.

While the number of nuclear power plants around the world decreases, in Brazil it increases. It is estimated that by 2050 Brazil will have up to 4 nuclear power plants. The big problem is that these plants have a useful life of 40 years. In 2024, the Angra 1 contract expires and measures are being taken to ensure that it continues to operate after this period.

Only Brazil, the United States, and Russia have enough capacity to increase the number of nuclear power plants in the country. Brazil has one of the largest uranium reserves in the world, located in Bahia, and also the capacity to enrich uranium.

Nuclear power is considered by many to be dangerous, and indeed it is. If in the wrong hands, it can become an extremely lethal weapon. However, for electricity production, it is an extremely viable energy. As with wind farms, if there is no wind, there is no energy. Or even generating electricity from sunlight. Nuclear production does not face such problems, its only dilemma is the generation of radioactive waste and also the fact of its high cost of implementation.

It is a market that has everything to grow in the country and everyone knows the nuclear capacity that Brazil has that is why they are increasingly trying to invest in this area and giving priority to the resumption of construction of Angra 3.

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