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Reactors Fuel Enrichment Process by Reconversion of UO_2 to UF_6

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1. Introduction

Currently, several models of safer, more efficient and compact nuclear reactors are being studied, however, several countries in the world where nuclear reactors are reliable sources of energy, first and second generation reactors are still used [1].
The Pressurized Water Reactor (PWR), model is the most widespread, with approximately 300 operational reactors for power generation and several hundred more employed for marine propulsion [2].
For this work, a PWR type reactor, manufactured, designed and sold by Westinghouse Electric Company, model AP1000, was analyzed. This reactor converts the UO_2 core into a (U-Th)O_2 core [3].
At AP1000, techniques are studied for reprocessing commercial nuclear fuel to obtain mixed oxide fuel (MOX), carried out in European countries and to a lesser extent in Asian countries such as India, Japan and Russia, China has plans to develop fast and reprocess [2].
This study intends to develop and improve the technology for the enrichment process and estimate the separative work, verify the neutron and thermo-hydraulic characteristics of the PWR reactor, in addition to modeling and analyzing the behavior of a pressurized water reactor with the SERPENT code. The proposal for the AP1000 is a first cycle with mixed U/Th adapted to the PWR to start the production of U-233. This core was defined through parametric studies [3]. It contains 157 fuel sets based on a mixture of uranium and thorium oxide with 20% UO_2 enriched at U-235 and rated thermal power of 3400 MWt.
The reactor has three regions composed of MOX (U-Th)O_2, with proportions of UO_2 in the MOX with proportions of: 32%, 24% and 16% by mass. The original geometric characteristics of the AP1000 Core, such as pitch, fuel diameter, gap and coating thickness, were kept unchanged [4].

2. Methodology

Although the purification technique is an industrial secret in many countries, there is a considerable variety of scientific methods found in the literature [5], which made it possible to select the most economical process and, at the same time, the most efficient for the process. In these categories, the gasified process called, Plutonium Uranium Recovery by Extraction (PUREX) stands out for the purification of U-3O8, applying the extraction by aqueous solution of an ongano-oxygenated solvent (diethyl ether, methyl-isobutyl-ketone and tributyl-phosphate) [5].
Uranium and Plutonium are extracted from the spent fuel in the form of Uranyl nitrate and Plutonium nitrate solutions. After purification and concentration, the Uranium and Plutonium products are converted into oxides [6].

The process can be seen in the flowchart in Fig. 1 below.

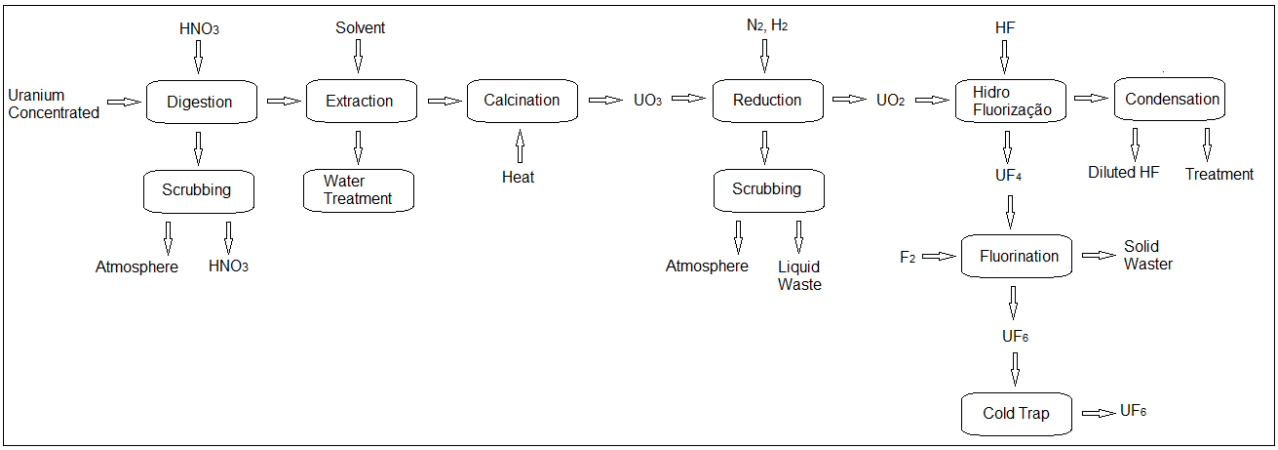

Figure 1: Flowchart of the UF_6 aqueous purification and enrichment process [5].

A chemical method was used where the UF_6 conversion plant produces fluorine by electrolytic decomposition of hydrofluoric acid.

The sprinkling speeds of gas molecules at a given temperature depend on their masses. Therefore, in a gas composed of molecules containing different isotope species, a molecule containing the light isotope will, on average, have a slightly faster velocity than that containing the heavy isotope, so it will come into contact with the wall of the containment container with more often. In the gaseous diffusion process, the container wall is the interior of a porous tube through which the diffusion takes place [7].

As shown in the following equations, the maximum theoretical separation that can be achieved is equal to the square root of the diffusion process ratio using Uranium hexafluoride [7].

Kinetic energy:

$$\frac{1}{2} MV^2 \tag{1}$$

$$\frac{1}{2} M_1 V_1^2 = \frac{1}{2} M_2 V_2^2 \tag{2}$$

Or

$$\frac{V_1}{V_2} = \sqrt{\frac{M_2}{M_1}} = \alpha^* \tag{3}$$

For Uranium isotopes in gaseous UF6, we will have:

$$\alpha^* = \sqrt{\frac{M_{U^{238}F_6}}{M_{U^{235}F_6}}} \tag{4}$$

A production of 90 percent by weight of U-235 from 0.711 percent by weight of U-235 material, as found in nature, requires about 3,000 serial diffusion stages. A plant built for the purpose of producing material up to 4.0 percent by weight of U-235, as might be required for typical light water power reactors, would contain about 1,200 stages [7]

Most of the plutonium available in the world is recovered by the Purex process [6]. Developments in

engineering technology have also had an impact on this process [6]. The development of single-cycle processes has brought advantages in terms of system maintenance and annular pulse columns that are safe in relation to criticality, in addition to the possibility of almost real-time accounting of fissile and fertile actinides, use of electrochemical *in situ*, photolytic and other techniques for reduction and partitioning of plutonium for a final process [6].

3. Results and Discussion

It is necessary to eliminate Plutonium, because although there are several reprocessing and enrichment techniques, the technique applied in this study involves more advantageous economic, efficiency and safety characteristics compared to other methods.

The proposed MOX mixing concentration ratio shows that it is possible to improve the production process by eliminating the poison that reduces the reactor efficiency.

The use of the SERPENT code together with Monte Carlo standard deviation modeling for process analysis makes research more practical and economical.

Returning lightly enriched Uranium from PWR fuel reprocessing for enrichment reduces the needs of natural Uranium, Thorium and separation work. In this Uranium, some U-236 is present and additional U-235 is needed to compensate for parasitic absorption in U-236 [6].

This study with the SERPENT code considers uniform fuel and moderator temperatures throughout the core which tends to increase the peak power factor. A similar uniform temperature model applied to the AP1000 produces a peak power factor only 2% lower than the AP-Th1000 configuration [4].

This study analyzes the aforementioned possibilities, irradiated Thorium processing focusing on alternative possibilities for solvent-free or non-aqueous online process routes for the treatment of high-burn fuels for the recovery of U-233.

4. Conclusions

The need for electricity for the production of consumer goods and services is a reality in society around the world and the prospect of an increase in demand is something considered for the near future. Of all the possible energy sources studied to date, energy from nuclear reactors is the most promising, whether due to the implementation cost, environmental impact, capacity produced or the continuity of production.

Nuclear reactors have been studied and developed since the mid-1940s and the pressurized water reactor being the most used around the world today.

Although there are more modern techniques, this work seeks to contribute by analyzing the possibilities of recycling and enriching Uranium exafluoride, through the optimization of known process techniques that are within the reality of the market today.

It is evident that in the heat generation process, the reactor will form waste that contributes to the reduction of the efficiency of the process, thus, it is necessary to apply engineering, physicochemical and physical techniques of nuclear reactors to verify the technically and economically feasible possibilities to significantly decrease the production of long-lived actinides destined for geological deposits.

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