бария, проведены экспериментальные исследования результаты, которых приведены в данной работе.

Исследования проводились на опытной установке, оснащенной пленочным выпарным аппаратом с нисходящим потоком при следующих технологических режимах: на водных растворах азотной кислоты и растворе-имитаторе рафината, при атмосферном давлении и разряжении, в интервале температур греющего пара от 116˚С до 135˚С, подача раствора варьировалась от 40 до 70 л/ч.

Установлено, что при концентрировании под атмосферном давлением степень упаривания была достигнута 6-ти. При разрежении 5 кПа степень упаривания достигала 12-ти. Оптимальная концентрация азотной кислоты, при которых не происходит осаждение нитрата бария, находится в диапазоне от 5,6 до 6,9 моль/л. Коэффициент теплопередачи находился в пределах от 2000 до 2200 Вт/(м^2*К) при интенсивности орошения теплообменной трубы от 700 до 750 кг/(м*ч).

Исследования показали перспективность использования пленочного выпарного аппарата с нисходящим потоком для концентрирования рафината от переработки ОЯТ с предотвращением образования осадка нитрата бария.

NPP SAFETY. RISK ASSESSMENT USING FUZZY LOGIC METHODS

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The Probabilistic Risk Assessment (PSA) method, popular in nuclear industry, does not provide valid risk estimates in cases of rare events, when there’s lack of information and uncertainty. The focus of this work is applying Fuzzy Logic approach for safety analysis of Nuclear Power Plants.

The main safety assessment method for complex systems in the classical theory of reliability is Probabilistic Safety Assessment (PSA). This is a comprehensive, structured approach in the form of a conceptual and mathematical tool for defining failure scenarios and obtaining numerical risk assessments.

However, the high reliability of technical systems, evaluated on the basis of the PSA, does not imply the actual security of those systems, since even highly reliable systems have some latent residual risk; that is, there is a possibility of a “rare event” with very significant damage. The residual risk comes from design decisions and technologies' specifics and implies a potential for a catastrophe. In the framework of “rare events” problem, the probabilistic approaches tend to be ineffective.

As an alternative to the traditional classical method of Reliability theory, which is widely used within the PSA and leads to deadlock schemes when trying to estimate risks of rare events, lies the need to create security evaluation and management systems

based on determining the level of security by comparing the estimated risks with acceptable levels, which, unlike PSA, would be applicable for rare events problems.

A measure of the security level of a system is evaluated via a set of “Risk Categories”. In cases where the probability of a risk event is almost zero or unknown, unreliable or cannot be calculated on the basis of statistics or system properties, a measure of risk as a degree of danger of a state or process, will objectively mean the real measurable danger. In these cases, for calculating risks of events occurring with probability of almost zero, become relevant, as an alternative to PSA, the methods of Fuzzy Sets and Fuzzy Logic theory.

Unlike standard logic with two binary states (1/0, Yes / No, True / False), Fuzzy Logic allows you to define intermediate values between standard estimates. In the theory of fuzzy sets, fuzzy numbers are introduced as fuzzy subsets of a specialized form corresponding to statements like “the value of a variable is approximately equal to A”. With the introduction of fuzzy numbers, it turned out to be possible to predict future parameter values that vary in the established calculation range. A set of operations on fuzzy numbers is introduced, which reduces to algebraic operations with ordinary numbers when specifying a certain confidence interval (level of belonging). The use of fuzzy numbers allows to set the estimated corridor of the values of the predicted parameters in the absence of data. As an example, in our work we consider the Mamdani algorithm for risk assessment of release of radioactivity outside the territory of nuclear power plants with a VVER type reactors.

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