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Experience with Soluble Neutron Poisons for Criticality Control at ICPP

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Soluble neutron poisons assure criticality control in two of the headend fuel reprocessing systems at the Idaho Chemical Processing Plant. Soluble poisons have been used successfully since 1964 and will be employed in the projected new headend processes. The use of soluble poisons (1) greatly increases the process output (2) allows versatility in the size of fuel assemblies processed and (3) allows the practical reprocessing of some fuels.

A soluble poison was first applied in the headend process for highly enriched uranium-zirconium alloy fuel.[1] The dissolver was basically a 324 mm ID cylindrical slotted fuel basket-charging chute enclosed in a pear shaped dissolver shell which was 610 mm ID on the lower portion and 1041 mm ID on the top section. The shell was 2.52 m in height. This dissolver was essentially the same as used previously without soluble poison but with the appropriate safe mass loading. Use of 3.8 g/liter natural boron in the acid feed to the dissolver safely allowed a tenfold increase in the zirconium alloy fuel processing capacity. The dissolver was eventually retired after 23000 hours of operation in which there were no notable problems due to the use of soluble poison.

The replacement uranium-zirconium alloy dissolver[2] was longer, to allow more fuel element submergence in the acid, and with a smaller shell diameter to reduce the amount of borated liquids necessary for operation and cleanout. This dissolver has an inner cylindrical and slotted 330 mm ID charging chute in a cylindrical 483 mm ID outer vessel that is 4.14 m high. The safety limit for all fluids entering the dissolver is 3.6 g/liter boron. To allow for possible deviations in the measurement systems and drift between analytical sampling periods, the standard practice is to use 3.85 g/liter boron as the lower limit. This dissolver has had 4000 successful hours of operation using soluble poisons.

The electrolytic dissolution process[2] depends on soluble gadolinium for criticality safety. This system is used to process high enriched uranium clad in stainless steel. Electrolytic dissolution takes advantage of the anodic corrosion that occurs when a large electrical current is passed through the fuel elements in a corrosive environment.

The electrolytic dissolver vessel is a long slab (162 mm side to side) which tapers to a "V" shape trough at the bottom. The height is 660 mm to the top of the overflow channel. The dissolver solution is circulated also through a surge tank and heat exchanger. In processing EBR-II fuel assemblies the safety limit requirement is 1.8 g/liter Gd in the acid feed to the dissolver. The failure limit for this process is considered to be 0.45 g/liter Gd in the dissolver solution. The heat exchanger cooling water loop is required to contain at least 2.6 g/liter Gd.

The electrolytic system incorporating soluble poison has operated for some 4000 hours. It is doubtful that the EBR-II fuel could have been reprocessed without it.

As the poisons must be present in acceptable quantities for the several headend process to operate safely, a high level of assurance is necessary in the make-up and use of each solution. Poisoned solutions are required for dissolving, for heel cleanout, for cushion water and for the closed loop cooling systems.[3]

Three control methods are used on each headend system. First, the poison is mixed according to standard operating procedures and the measurements are affirmed by the operator's supervisor. Second, the poisoned solution is stirred, sampled, analyzed, and the analysis reported while still in the mix tank. Finally, a Nuclear Poison Detection System (NPDS) must show an acceptable poison concentration before the solution can be transferred. The NPDS provides a continuous monitoring of the boron concentration in the solution and automatic alarm and shutoff of the acid feed valves should the poison concentration drift out of specified limits. The NPDS system consists of a neutron source and two independent detection, alarm and flow stoppage systems. The PuBe source and two BF_3 neutron detectors are immersed in the mix tank. As the poison concentration is increased, more neutrons will be absorbed by the poison and fewer neutrons will reach the detector. The two channels of the system are kept separate to avoid a common mode failure. A reliability analysis of the NPDS has indicated an anticipated system failure each 350 years of continuous operation. This is but one of three assurance systems and the other systems would also have to fail and an abnormal fuel distribution in the dissolver system would be required before a criticality due to insufficient soluble poison could occur.

Major dissolver process upset conditions which must be considered are (1) precipitation of the poison, (2) precipitation of the uranium, and (3) dilution of the poison. Condition (1) must not be possible. The possibility of condition (2) will likely set the poisons concentration limits and must not result in an unsafe dissolver. The consideration of condition (3) will affect the poisoning of heat exchanger and dissolver jacket fluids and the allowance for water within fuel assembly storage cans.

The major disadvantage of using soluble poisons is the need for very sophisticated control systems and procedures, which require extensive checkout. The need for a poisoned primary heating and cooling system means a secondary system is needed as well. Experience has shown, however, that production enhancement more than makes up for the problems.

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