PULSED PNEUMATIC TRANSPORT OF SOLID WASTES FROM REPROCESSING OF SPENT NUCLEAR POWER PLANT FUEL TO STORAGE

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The results of experimental investigations of the effect of a gel-like residue on the transport of pieces of structural materials of fuel assemblies from nuclear power plants by a pulsed pneumatic transport system to storage are presented.

The data obtained show that even increasing the viscosity of the wetting medium substantially (by a factor of 100) has little effect on the transport regime and technology. 3 figures, 2 tables, 4 references.

Among other basic factors, the removal of insoluble fragments of spent fuel assemblies to storage after the fuel has been leached out determines the output of the main process stages and the radiochemical plant as a whole. According to the initial plan, such removal was conducted in cans and stringent requirements had to be satisfied in order to prevent accidents. After 10 years of plant operation, the removal of solid wastes in cans to storage from reprocessing of spent fuel assemblies was replaced by an efficient, ecologically safe, pulsed pneumatic transport method.

Ordinarily, after the fuel is leached out and washed, the pieces of the structural materials of fuel assemblies (the main fraction ranges from 5 to 35 mm) enter a pulsed pneumatic transport system with a moisture content not exceeding 7%, which does not affect the transfer of the solid wastes to storage. However, when the fuel is recovered from individual fuel assemblies, small insoluble particles as well as insoluble sediments, which must also be removed to storage together with the pieces of the structural materials of the fuel assembly, form in the dissolution apparatus [2, 3].

When fuel assemblies are cut mechanically, large pieces as well as small particles are formed [3, 4]. For this reason, the addition of small insoluble particles during transport of solid wastes has no effect. However, some sediments consist of a gel, which gets into the pieces of the structural materials of the fuel assemblies and can influence the technological conditions under which the solid wastes are transported to storage.

The present work is concerned with the investigation of the effect of this sediment on the process.

The investigations were performed on model and semicommercial setups with a mixture consisting of simulators of cut pieces of fuel assemblies (86 mass%) and TU-6-09-426-75 aluminum oxide (14%), which was used, at the recommendation of the Industrial Association Mayak and the Federal Science Center of the Russian Federation – A. A. Bochvar All-Russia Scientific-Research Institute of Standardization in Machine Engineering, as the main component of the sediment with the obligatory presence of at least 5 mass % water.

The model apparatus consisted of a 9.3 m long, straight pipe (path) 5 with an inner diameter of 36 m, and a hopper 4 through which the transported material enters (Fig. 1). The gas pulse was applied from a 1.8-liter receiver 2 through a special valve 3. The nozzle was 10 mm in diameter. The apparatus was controlled from a panel 1. After transport, the pieces entered the receiver 6.

A mixture of metal particles consisting of $3 \times 4 \times 0.2$ mm plates and 4 mm in diameter and 4 mm high steel pellets was used to simulate the pieces of the fuel assemblies. Their mass ratio was 1:2, and the mass of one batch of the mixture loaded was 100 or 300 g. In the experiments, the initial pressure in the receiver $P_{in}$ was varied from 1 to 2.5 MPa and the final pressure $P_f$ was varied from 0.5 to 1.5 MPa.

The semicommercial setup (stand) simulated as closely as possible the pulsed pneumatic transport system at the radiochemical plant Mayak. It consists of an apparatus for dissolving the fuel in the fuel assemblies, whence the mixture was off-loaded into a hopper. Then, a special shutter cut off the apparatus from the transport system. The mixture was mixed along a 120 m long pipeline with two rises to heights of 7 and 16 m and two 0.4 m in radius turns by 90° and 180° and one 1.5 m in radius turn by 140°. The inner diameter of the straight pipe was 250 mm. In addition to the main nozzle, three additional nozzles were placed in front of the hopper: two nozzles were placed in front of the rises and one nozzle was placed in front of the rise into the receiver.

The simulators of the fuel assembly pieces consisted primarily of 8 mm long and 9.2 and 12.6 mm in diameter segments and pipe segments with 0.1 mm thick walls. One batch of the mixture had a mass of up to 450 kg. Transport was effected with a gas pulse from a 1.6 m$^3$ receiver with a pressure drop $P_{in}/P_f = 2/0.8$ MPa.

According to previous investigations [1], the pieces can move in two regimes: with complete cleaning of the pipe, for which another or several cycles of gas pulses are applied without introducing a new batch of pieces, and with the transferred residue, when a second batch is loaded immediately after the first cycle. In the latter case, a residue consisting of about 10% of the mass of the loaded batch is formed.

In experiments on the model, one batch of the mixture was loaded into the hopper 2 (see Fig. 1) and a gas pulse was introduced via the panel 5 from the receiver 3 through the valve 4 into the pipe 1. This batch was moved completely or partially into the receiver 6.

Another gas pulse was required to clean out the model pipe completely in the first regime. In the second regime, a new batch of the mixture was loaded after the first gas pulse and the process was repeated. The transported mass of the mixture in the hopper was weighed after 10, 15, and 20 pulses.

The experimental results are presented in Table 1. The experiments showed that the mixture is moved completely for all parameters investigated, except the lowest pressure or a pressure drop with a moisture content ranging from 8 to 9%. However, for longer durations of the process (20 cycles), complete transport of the particles occurs.

A similar improvement in the movement of the mixture can be attained by increasing the initial gas pressure to ≥1.5 MPa in the receiver or the pressure drop to 1.5/0.5 MPa.

Experiments performed on the model made it possible to switch to experiments on a semicommercial apparatus. In this case, a batch of the mixture was off-loaded from the dissolution apparatus into the hopper and partially distributed along the entire pipeline. The mixture batch was moved into the receiver by successive gas pulses in the nozzle.

The experiments showed that irrespective of the moisture content (from 0 to 15%), the batch of pieces with the sediment simulator (aluminum oxide) was completely removed into the receiver, just as pieces without sediment, in two complete cycles of successive gas pulses applied through nozzles located along the path. All this was confirmed by weighing the pieces entering the receiver and by additional examination of the inner surface of the pipeline through special hatches placed along the path of the semicommercial apparatus. Figure 2 shows the inner surface of the pipe along the path after the mixture is off-loaded from the dissolution apparatus near the receiving hopper. The mixture 1 can be seen clearly, and the moist aluminum oxide 2 stuck on it can be seen on the inner lateral surface. Only traces of the moist aluminum oxide (white traces in Fig. 3) are observed on the inner surface of the pipeline after two successive cycles of gas pulses.