SYSTEM FOR THE DECONTAMINATION OF A DRUM-TYPE FILM EVAPORATOR HEATING SURFACE FROM SALT DEPOSITS

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The paper presents some proposals regarding the decontamination of drum-type film evaporator heating surface from salt deposits resulting from the evaporation of liquid radioactive waste. It presents the solution flow modes in a rotating drum given the application of a surface decontamination system.

Keywords: *liquid radioactive waste, modeling of solutions, drum-type film evaporator, surface decontamination, salt deposits, radioactive waste.*

Introduction

An installation with a drum-film evaporator (BFE) has been considered among promising systems for liquid radioactive waste processing [1]. The installation evaporates low- and intermediate-level liquid radioactive waste (LRW). Structurally, the evaporator involves a horizontal drum partially filled with the evaporated solution. It is equipped with systems supplying the initial solution, withdrawing the concentrate and the generated steam. A space for a heating steam jacket is formed by the outer sealed casing and the outer surface of the drum.

Initially, the system is heated by an external heat source. Then it is operated based on MVR technology (Mechanical Vapor Recompression): the steam generated in the drum is fed to the Roots pump, in which it is mechanically compressed and heated. This steam is used as a heating one in the drum steam jacket.

Solution concentrated to a salt content of 700 g/l is regularly removed from a rotating drum through a pipe into an evacuated container (Figure 1).

Salts formed due to solution evaporation settle on the inner surface of the evaporator drum impairing heat transfer [2]. To increase the performance, evaporating equipment shall be fitted with a passive surface cleaning system. For this purpose, it was proposed to use a screw placed freely in the evaporator drum (Figure 2). When the drum rotates, the screw rotates as well, cutting off the settling salts resulted from LRW evaporation by the cutting edge of the spiral and supplying them to the unloading station.

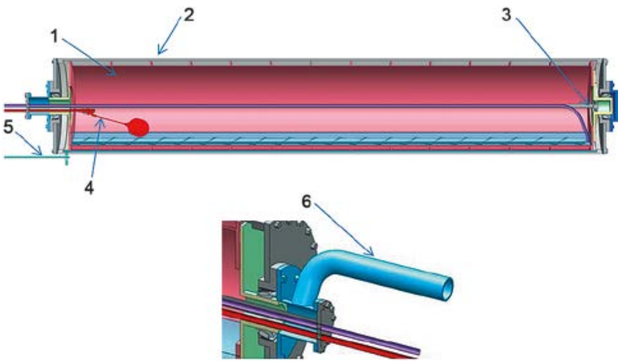

Figure 1. Layout of a drum-film evaporator: 1 — heating drum; 2 — outer casing; 3 — concentrate outlet pipe; 4 — pipe supplying the evaporated solution; 5 — condensate drain pipe; 6 — steam outlet

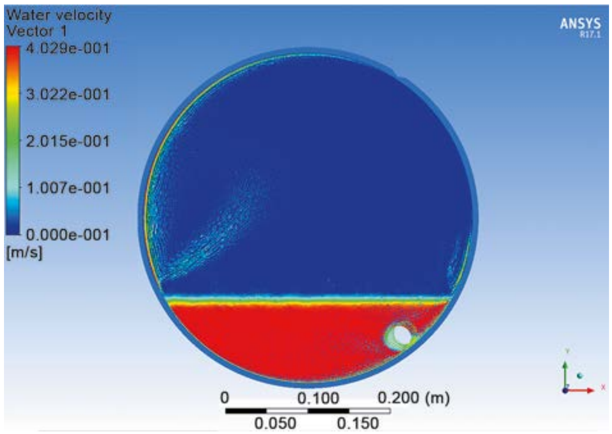

Figure 3. Rate distribution for medium particles in the evaporator drum with a screw

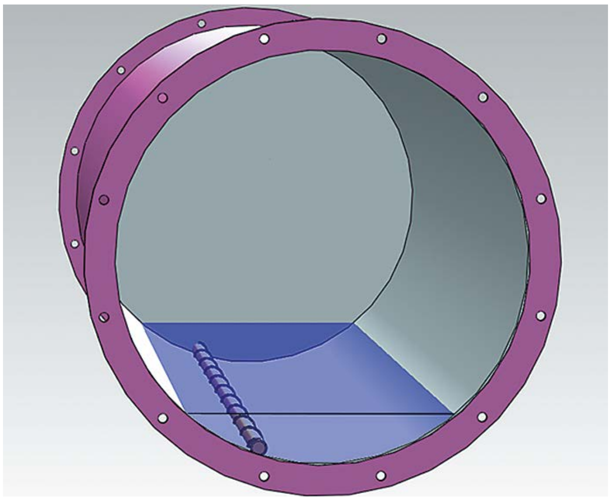

Figure 2. Screw layout in the evaporation drum

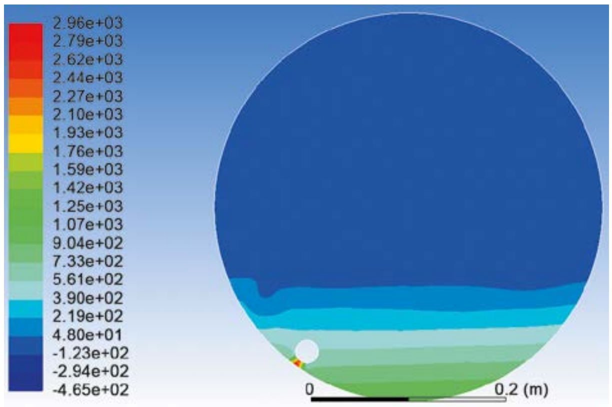

Figure 4. Medium density distribution in the evaporator drum with a screw taking into account the three media considered

Model of liquid behavior inside a film drum-evaporator

To check the performance and to identify such potential phenomena as splashing, foaming, droplet entrainment, calculations were performed based on the ANSYS 17 CFX and Fluent software. A mathematical model of the drum with auger was built and its rotation was set to 14 revolutions per minute. The results shown in Figure 3 demonstrate that the water surface is smooth, with neither disturbances nor splashes.

A model providing the consideration of at least three media [3] (air-water-concentrate) was built in ANSYS 17 Fluent software. The calculation results shown in Figure 4 evidence for concentrate positioning at the bottom of the drum.

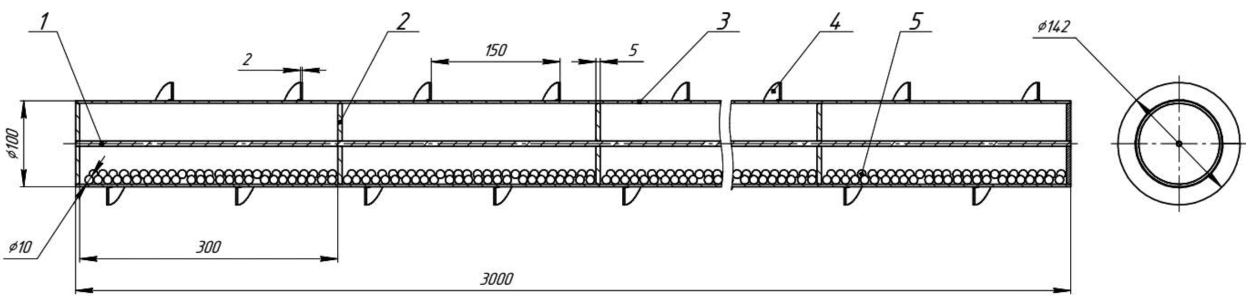

Figure 5. Longitudinal section of the screw: 1 —axis, 2 — baffle, 3 — pipe, 4 — spiral, 5 — ball

Passive auger salt ejection system

Salt can potentially settle on the surface of the auger. To eliminate this problem, a technical solution shown in Figure 5 was proposed.

Cells are arranged inside the screw: these are formed by partitions fixed on the axis and additionally serving as stiffening ribs. Metal balls are placed between the partitions. The balls have same completeness inside the cells, but are different in their weights. When moving, the balls produce vibrations due to collisions, transfer them to the auger and thereby impede salt deposition on the cutting surface. The same set of balls inside the cells avoid auger misalignment inside the drum.

Experiments testing the performance of a system designed for salt removal from the screw surface

To test the performance of the screw cleaning system, a model unit was assembled (Figure 6) in the laboratory of the Dimitrovgrad Institute of Engineering and Technology run by the National Research Nuclear University MEPhI and relevant experiments were performed.

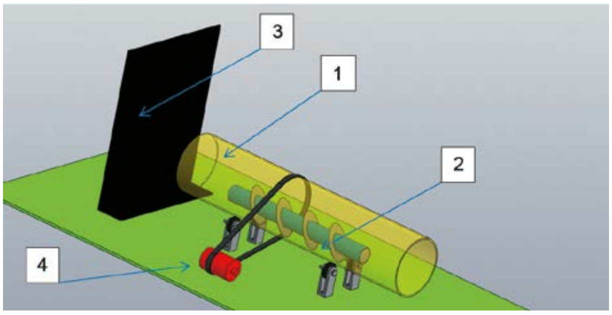

Figure 6. Layout of the experimental unit: 1 –drum, 2 – screw, 3 – screen, 4 – engine

The drum was rotated by an engine on wheel supports at a speed of 14 revolutions per minute. Two screw installation layouts inside the drum were considered: with and without a cleaning system.

Finely ground white sugar crystals no larger than 0.2 mm simulated salt deposits from LRW evaporation. The time of the experiments was limited.

To compare the efficiency of the auger options, a software was developed providing thirty photographs in each experiment and counting the number of suspensions (Figure 7) discharged from the auger by filling them into a table in an ascending order.

Three tests were carried out for each screw option. Table 1 presents the recorded results.

Figure 7. An example of a photograph that allowed to picture the suspensions discharged from the auger

Table 1. The number of particles recorded in experiments

№	Screw with a salt dumping system			Screw without a salt dumping system		
	Experiment №1	Experiment №2	Experiment №3	Experiment №4	Experiment №5	Experiment №6
1	82.00	70.00	103.5	106.5	51.5	94
2	120.00	90.50	111.5	116.5	114	106
3	121.50	102.00	155.5	121	130	112
4	124.50	107.00	166.5	123	143	121.5
5	125.00	137.00	175	128.5	149.5	140
6	126.00	173.50	176	132	154	149
7	138.50	178.50	184	137	157	157.5
8	140.50	198.00	191	141.5	157	162.5
9	152.00	212.00	195.5	145.5	158	166.5
10	152.50	213.50	200	152	160	171.5
11	153.50	235.50	206.5	154.5	165	182.5
12	155.50	241.50	212	158	168.5	203
13	165.50	244.00	214	163.5	170.5	210
14	174.00	254.00	224.5	167	181	211
15	180.00	256.00	233.5	175	184	216.5
16	183.00	260.50	238	177.5	185.5	225
17	190.50	264.00	243	181.5	188.5	228.5
18	208.00	269.50	246	185.5	192.5	238
19	213.00	275.50	250.5	188.5	201.5	242
20	214.50	286.50	253	188.5	204.5	247.5
21	221.00	287.00	259.5	191	207	250
22	227.00	296.50	262.5	194.5	209.5	255

Continuation of Table 1

№	Screw with a salt dumping system			Screw without a salt dumping system		
	Experiment №1	Experiment №2	Experiment №3	Experiment №4	Experiment №5	Experiment №6
23	231.00	303.00	273.5	206.5	225	258.5
24	233.50	312.50	275.5	211.5	234.5	266.5
25	236.50	322.50	290.5	213	237	271.5
26	239.50	330.50	298	216.5	240.5	293
27	252.00	354.00	302.5	224.5	258.5	299
28	279.50	360.50	306.5	245	275.5	319
29	285.50	375.00	324	263.5	295.5	327.5
30	291.50	401.00	342	272	360	454.5

When arithmetic average for the number of particles was calculated for each experiment, the efficiency of the screw fitted with the cleaning system turned out to be 13.1% higher.

Conclusion

The results obtained have demonstrated the prospects of screw application as a system that could clean the heating surface of drum-film evaporators from salt deposits resulting from LRW evaporation. The use of a salt dumping system extends the evaporator equipment lifetime with no interruptions required to clean the heating surface from salt deposits.

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