

DEVELOPMENT OF URANIUM OXIDE POWDER DOSING FOR FLUORIDE VOLATILITY SEPARATION PROCESS

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Abstract

The uniformity of dosing of powdered ceramic spent fuel into the reaction chamber of the flame fluorinator is an important assume for the preparation of volatile fluorides.

The dosing of U_3O_8 powders of varying granulometric composition by vertical screw feeder was studied at the NRI Rez plc.

The aim of these preliminary experiments was to describe qualitatively the shift of U_3O_8 particles and to find suitable screw and cone for the demanding uniformity of the falling powder.

The dosing rate was investigated with weighting and by radioactivity measurement of falling uranium oxide particles. Instantaneous values of the dosing rate were measured by trapping of dosed U_3O_8 powder on moving paper belt and fixed. The paper belt was cut into the strips and gamma radioactivity was measured.

The proposed method of dosing powdered U_3O_8 by means of vertical screw feeder is suitable for following uniform dosing of U_3O_8 powder: fraction 92 % powder with particle size 50 – 100 μm and fraction 8 % powder with particle size 0 – 50 μm , dosing rate 0.4 – 3.0 kg/h. No particle agglomeration or pressing took place during the dosing process, arching in the storage bin was prevented by helical belt mixing adapter connected to the pull rod.

The semi-pilot plant model for the experiments was constructed with regard to the possibility of connection of feeder to the input flange of a flame fluorinator.

1. Introduction

A great part of research capacities in the spent nuclear fuel transmutation is devoted to the research of the chemical separation procedures [1, 2]. Prospective systems show to be the ADTT (Accelerator Driven Transmutation Technology) or ADS (Accelerator Driven System) processes, the latter one utilizing a transmutation reactor with liquid fuel. This process is completed by a continuous radiochemical reprocessing allowing the continuous separation of spent fuel transmuted components and returning of the not yet transmuted components back to the transmutation process.

The pyrochemical reprocessing method in which the fuel matrix would also be the main carrier in the course of the separation process might be very advantageous in the liquid fuel transmutation reactor processes considered. The conception of the Nuclear Research Institute

in Rez [3] is based on the experience acquired in the development of a fluoride spent fuel reprocessing method operated in a pilot plant installation FREGAT within the scope of cooperation with Soviet specialists. This process is based on the fluorination of spent fuel in a powder form and on the uranium and plutonium separation in the form of volatile hexafluorides. Uniform feeding of the powdered U_3O_8 of suitable granulometric composition in the flame fluorination was found to be a prerequisite for a high process efficiency as found in experiments carried out in the Fluorine chemistry department of the NRI in Rez. Refining of the UF_6 product performed by condensation, sorption and distillation methods is a subject of other papers.

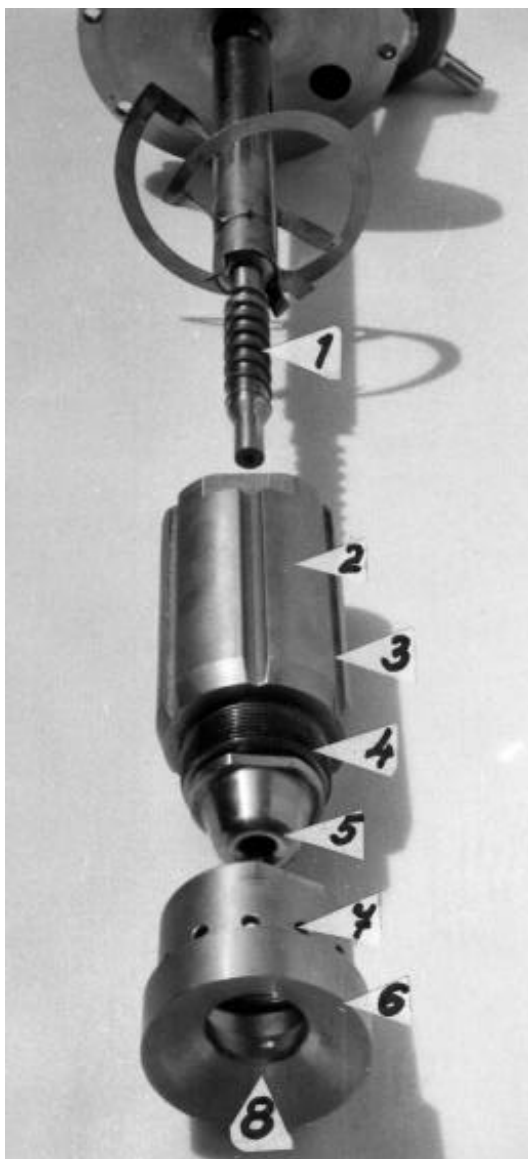
Experiments on the dosing of various powdered U_3O_8 mixtures by a vertical screw doser concentrated on uniform dosing of mixtures with defined granulometry are described on this paper.

2. Vertical screw doser

The powdered uranium oxides are dosed either by a fluid technique system (4) or by using a horizontal doser (5). The first method utilizing lift and carrying away of fine particles by an inert gas stream is disadvantageous for our purposes, as the introduced fluorine is diluted. A certain minimum particle size, perfect combustion of the introduced material and its relatively small size is prerequisite for uniform dosing of powdered material by a vertical screw doser. The function tests of a screw equipment for U_3O_8 dosing carried out at the fluorine chemistry laboratory of the NRI Rez are described in this contribution.

The vertical screw doser was designed at the VUChZ Brno according to the technical conditions of the test reprocessing line, requiring uniform and continuous delivery of powder in the fluorinator for one thing and tightness and possibility of remote control in a hot cell for another. The inner part of the vertical screw doser with components for reactants mixing is illustrated in Figure 1.

Vertically mounted perfectly machined screw is rotating with a variable speed in a vertically grooved screw chamber. This arrangement should eliminate turning over and compression of dosed material in the screw threads which could take place under the effect of gravitation in the screw axis direction (by contrast with the horizontal screw dosers). A functional nickel vertical screw doser connected to the fluorinator in a fluorinating line is shown in Figure 2.



- 1 - screw
- 2 - mixer body
- 3 - grooves for fluorine inlet
- 4 - control of fluorine input rate
- 5 - nozzle
- 6 - mixer head
- 7 - openings for fluorine inlet to the nozzle
- 8 - openings for fluorine inlet to the U₃O₈

Fig. 1. Internal part of the vertical screw doser with components for mixing of reactants



Fig. 2. Vertical screw doser connected to the fluorinator

In the dosing tests, the dosing uniformity was evaluated by the spread of dosing rates (in percent) measured in 1 minute intervals at the dosing rates of 1–3 kg/hr. For the dosing of U_3O_8 into the flame fluorinator it is advantageous to observe the continuity of the dosed powder column and to evaluate it radiometrically by considering the dosing rates spread in very short time intervals (0.1 s).

3. Experimental

A method for the dosing rate (1–3 kg/hr) determination by measuring the dosed U_3O_8 powder gamma radioactivity (8) was developed. This method was utilized to ascertain the most suitable design solution of basic parts of the doser (screw profile, screw bushing etc.) as well as for the dosing uniformity estimation, as described in several NRI reports (6, 7). The spread of the U_3O_8 powder during its capture on a paper band moving below the doser mouth was evaluated in a similar way. The dosing rate was determined by measuring gamma radioactivity of band sections corresponding to the time interval of 0.1 s. This method enabled us to evaluate the dosing uniformity in very short time intervals as required by the technical conditions of the dosing equipment of the fluoride reprocessing line (maximum spread of $\pm 100\%$ for the measurement in time intervals of 0.1 s in the course of 1 minute).

A nickel screw doser was designed and manufactured on the base of results of tests with a doser model. The inner part of the doser is shown in Figure 1 together with the components for mixing of reactants. The doser was connected to a driving unit consisting of a gearbox with a gear ratio of 50:1 and a d-c electric motor with a dynamo tachometer. The electric motor revolutions were varied by using a thyristor converter, thus controlling the screw doser revolution.

4. Results and evaluation of tests

The results confirming the assumption on uniform dosing were obtained for the basic U_3O_8 powder tested with the granulometric range of 50–100 μm and of all more coarse fractions. Uniform and continuous dosing was attained if the above powder was diluted with a finer U_3O_8 fraction of 0–50 μm up to its proportion of 8 %. When dosing these powders, sufficiently strong retarding forces of the U_3O_8 layer on the finely grooved Monel bushing are acting and the particles are uniformly moved by a screw of a suitable design (the carrying shank diameter is increasing along the screw length of 75 mm from 14 mm to 16 mm at the doser mouth).

Friction between particles is increasing with the decreasing powder liquidity (i.e. when the fine fraction (0–50 μm) proportion exceeds 8 %), the powder is only turning over and dosing is interrupted. The doser cannot be recommended in this case and the U_3O_8 particles mixture with the granulometric composition of 92 % of the 50–100 μm fraction and 8 % of 0–50 μm fraction is to be considered as a limiting one for the given doser type. An U_3O_8 mixture designated as α could also be used for feeding U_3O_8 into the fluorinator. It is composed of 0–50 μm fraction (15 %), 50–100 μm fraction (25 %), 100–160 μm fraction (30 %), 160–200 μm fraction (20 %), and 200–250 μm fraction (10 %). Uniformity of U_3O_8 dosing in very short time intervals (dosing continuity) for various mixture compositions is shown in Figures 3 and 4 obtained by a capture of the dosed powder material on a moving paper band (9).

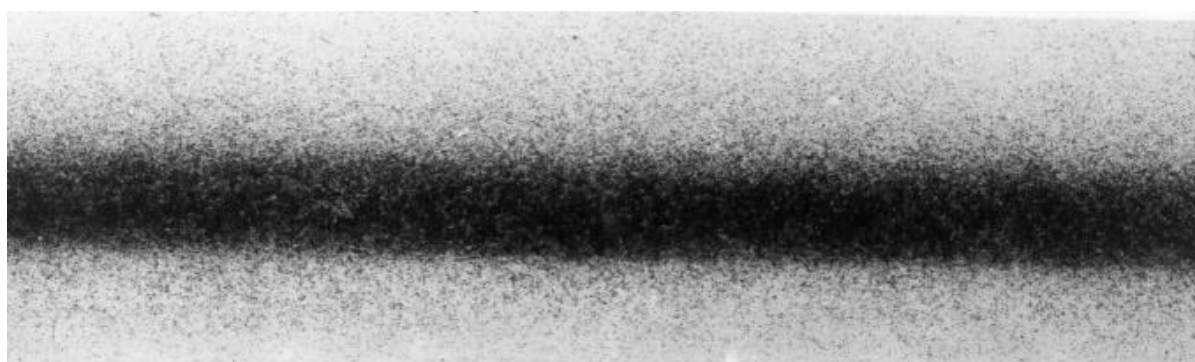


Fig. 3. Band diagram of dosing 50-100 μm fraction of U_3O_8 at the dosing rate of 3 kg/hr

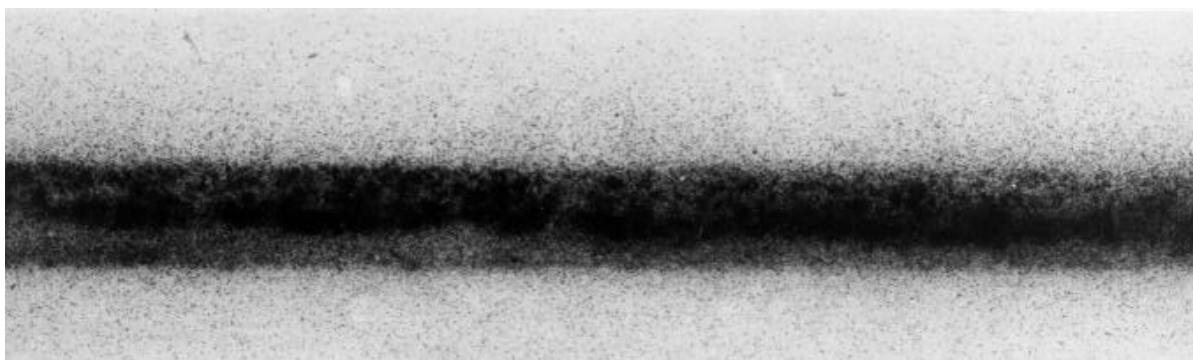


Fig. 4. Band diagram of dosing U_3O_8 powder mixture composed of 93 % of 50–100 μm fraction and 7 % of 0–50 μm fraction. Dosing rate of 3 kg/hr.

Operational characteristics of the screw doser used for dosing U_3O_8 into a flame fluorinator is depicted in Figure 5. The linear character of dosing rate dependence on the revolution number of the doser screw could be also observed for the U_3O_8 mixture designated as α .

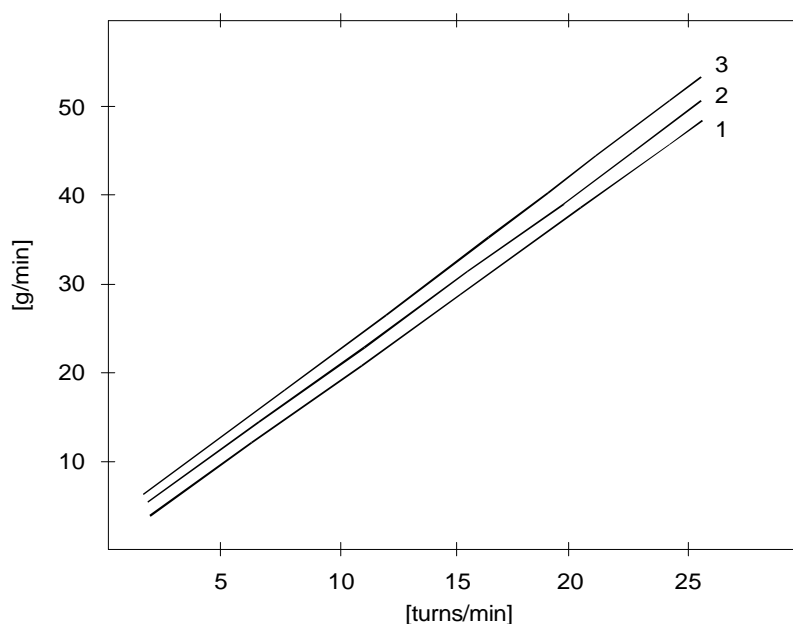


Fig. 5. Working characteristics of the vertical screw doser

The change of the amount of charge in the doser storage bin in the course of dosing did not affect the dosing rate of the powdered material. The particle agglomeration and arching in the storage bin was prevented by helical belt mixing adapter connected to the pull rod.

The quantitative evaluation of the uniformity of dosing by the vertical screw doser is given in Table I.

Mixture composition U ₃ O ₈ [%]		Dosing uniformity	Dosing continuity	dosing characteristics
50–100 µm	0–50 µm			
100	0	2,0%	21,8%	uniform, continuous
96	4	3,2%	32,4%	uniform
92	8	3,8%	62,4%	uniform with a certain proportion of agglomerates, satisfactory

Uniformity is expressed by the range of dosing rate values measured in 1 minute intervals in the course of dosing 1 kg of the powder.

Continuity is quantified by a percentual range of dosing rate values measured in the intervals of 0.1 s in the time of 1 minute.

The values of dosing uniformity and continuity of the α mixture are approximately the same as the values of the 2nd mixture given in the Table containing 96 % of the 50–100 µm and 4 % of the 0–50 µm fractions.

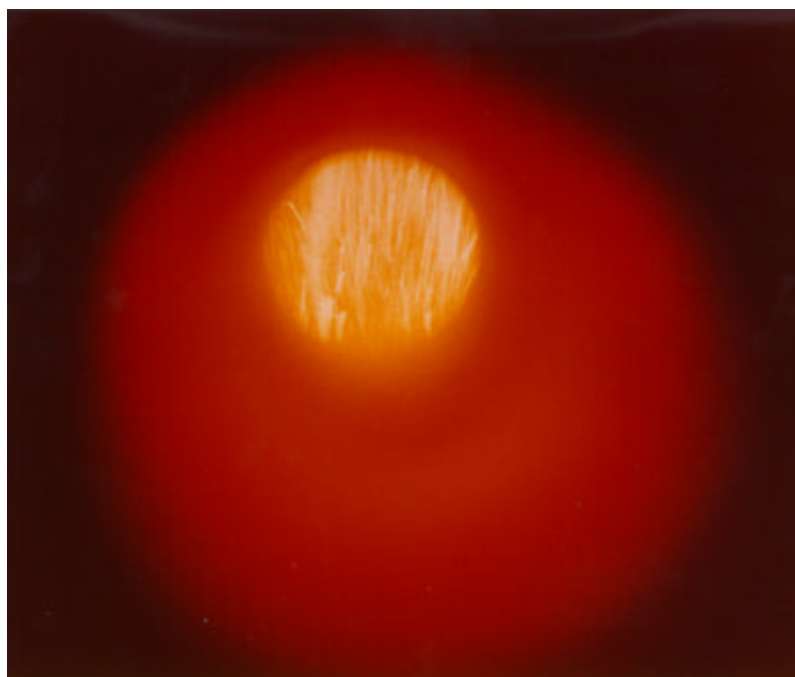


Fig 6.: Reaction of U₃O₈ powder particles

Picture 6 illustrates the reaction of U₃O₈ powder particles (92 % of 50–100 µm fraction and 8 % of 0–50 µm fraction) with fluorine gas. The process taking place in the fluorinator and other technological processes applied are described in the Final NRI Report of 1988 (11).

5. Conclusions

The results of the vertical screw doser testing indicate that it could be used for dosing the U₃O₈ material with a limited content of the fine fraction only, thus presenting demanding requirements on the preparation of U₃O₈ by the controlled oxidation of UO₂ pellets.

In order to allow the application of finer fractions of the U_3O_8 powder a vibration doser of powder materials with the dosing rate of 0.1–10 kg/hr was developed and tested in the NRI Rez (12, 13). Accurate adjustment and holding of constant dosing rate and dependence on other dosing process factors presume some design improvements of the dosing equipment. The application of a vibrating cone in the discharging opening for dispersing the U_3O_8 powder, in a similar way as it had been used in the vibration doser (14), was proposed for the classical horizontal double-screw doser to eliminate the non-continuous dosing in agglomerates in the region of higher dosing rates.

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