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Nuclear
Fuel
Cycle
Evaluation

INFCE

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BASE CASE PU-NITRATE TO PU-OXIDE CONVERSION PLANT

Co-Chairmen/WG 4/61 (B)
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TASK 7c)

BASE CASE First Draft

Fuel fabrication facility

I. Conversion plant

Draft prepared by experts of the
Federal Republic of Germany

BASE CASE CONVERSION PLANT

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1. Introduction

The plutonium recovered in the course of reprocessing of spent fuels is obtained in the form of nitrate, whereas the needs for the starting material to fabricate plutonium-containing fuel rods is PuO_2.

The conversion plant is the first general step to bring the plutonium nitrate into the chemical form where the fuel material may be used as a basic material for the mixed oxide containing fuel rods.

2. Conversion plant

The chemical process of converting of Pu $(NO_3)_4$ to PuO_2 is achieved by precipication followed by calcination. The precipitation process may be continuous or discontinuous. In order to produce PuO_2 with necessary and reproducible specifications the precipitation as Pu (IV)-oxalate is chosen.

The following precipitation and calcination reactions are involved:

$$Pu(NO_3)_4 + 2\ H_2C_2O_4 \longrightarrow Pu(C_2O_4)_2 + 4\ HNO_3$$

$$Pu(C_2O_4)_2 \cdot 6\ H_2O \xrightarrow[T]{N_2} PuO_2 + 2\ CO + 2\ CO_2 + 6\ H_2O$$

Fig. 1 illustrates the necessary process steps and shows that the production of a certain amount of PuO_2 requires different liquid and gas quantities depending on the respective process steps. The precipitation agent oxalic acid is added. This technique allows to increase the precipitation capacity and to reduce the volume of the liquid wastes.

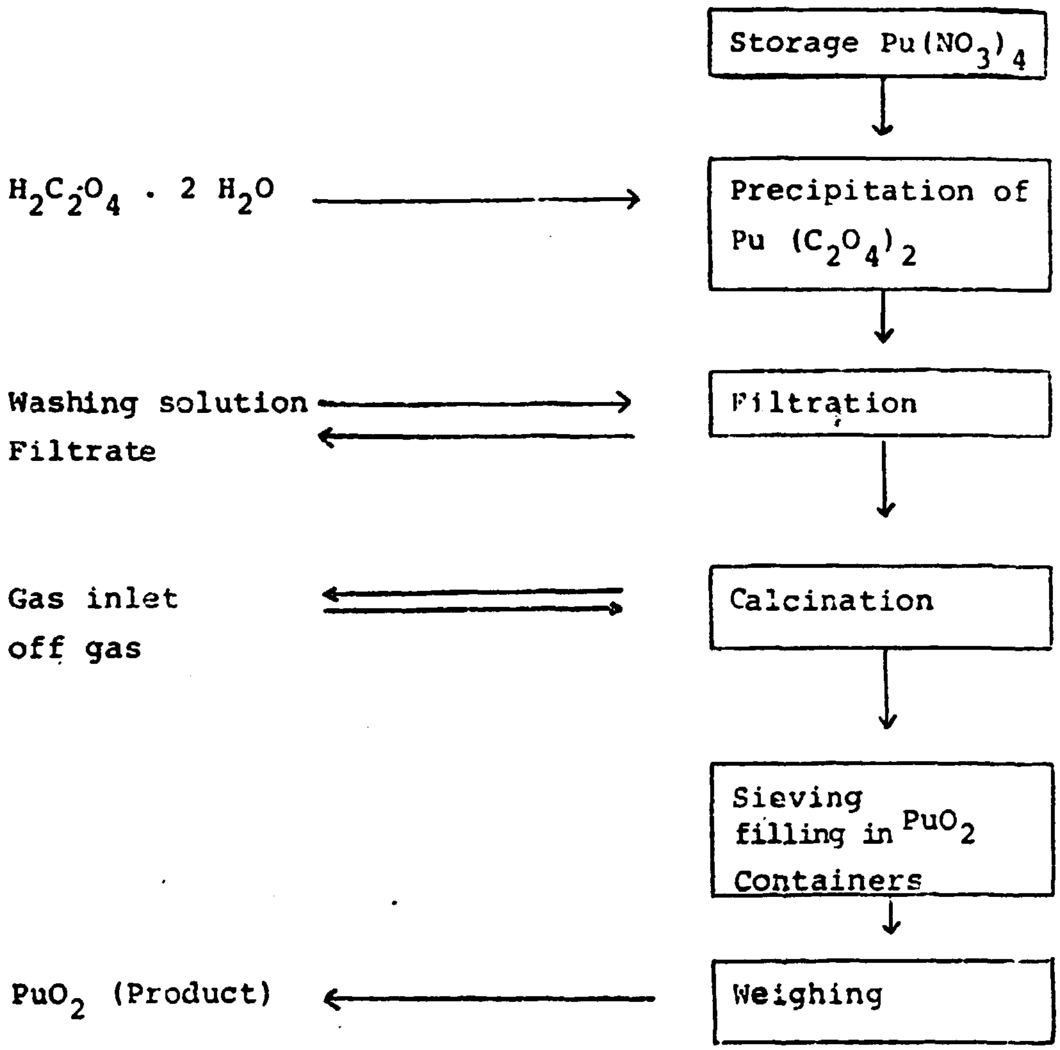

Fig. 1 Conversion flow sheet

3. Special design criteria

Besides typical criteria applied in chemical process engineering, the process design has to be based on various nuclear engineering features.

3.1. Radioactive contamination

In order to prevent radioactive contamination of personnel compartments and buildings, and to reduce the dose commitments, the glove boxes, compartments and the building are divided into subsequent negative pressure zones by means of an exhaust and ventilation system. The tanks not enclosed in glove boxes are subjected to particularly strict leak-tightness and welding seam quality tests.

The radiation exposure is reduced by controlling the sequence of process steps from the outside and by additional shielding of tubes and entire glove boxes.

3.2 Criticality

In order to exclude the possibility of a nuclear chain reaction, the facility components are designed and arranged on the basis of criticality calculations assuming the highest possible reactivity parameters such as full reflection and maximum plutonium content and density achievable.

The facility design is generally based on the principle of safety by geometry. In addition, the principles of safety by heterogeneous poisoning moderation and material flow limitation are equipped with neutron absorbers constantly in operation.

Boron-containing glass raschig rings were chosen for distillate tanks and for those bottom troughs of glove boxes in which the safe layer thickness might be exceeded in the event of escape of plutonium nitrate due to a leak or fracture. Each tank contains a central boron carbide rod.

The principles of safety by moderation control and by material flow limitation were used for "dry" glove boxes and for those glove boxes where only small quantities of plutonium are manipulated.

3.3 Maintenance and replacement

In this facility the equipment components are arranged in such a way that maintenance and replacement can be carried out quickly and easily in compliance with radiation protection regulations and also to reduce costly shutdown time. Therefore only well proven components are used and installed in such a way that, whereever possible, only the parts in contact with the product are located inside the glove boxes.

3.4 Corrosion

Corrosion is prevented by appropriate selection of materials. Materials for tanks, components and piping are metals, glass and plastics. Glass is chosen for the precipitation column, the filtrate evaporator and some auxiliary aggregates.

4. Process description

The filling station and the storage tank battery are separately installed in order to limit any spread of contamination. The incoming flasks with plutonium nitrate are weighed in the filling station, then emptied by suction and flushed several times by internal spraying with diluted HNO_3. The plutonium nitrate solution flows from the filling station to the storage tank battery. The tanks are so interconnected that their contents can be intermixed.

The solution is sucked via intermediate tanks into the precipitation column. This column is equipped with external coils and/or cooling circuits, connected with separate heating.

After the plutonium nitrate solution is conditioned, oxalic acid is fed into the column. The plutonium oxalate suspension formed by precipitation is pumped into the filtering unit where the separation of the suspension is achieved by suction. The design of the unit makes the precipitate form a thin layer cake. After filtering the plutonium oxalate cake is tipped into a calcination tray. The charged calcination trays are pushed into the furnace by a chain conveyor. The calcination step is appropriately controlled.

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The calcinated product is slowly cooled down.

After cooling, the PuO_2 powder is transported into a sieving machine. The sieved PuO_2 powder is then filled into a container by a dust-free technique and is weighed.

5. Safeguards and physical protection

The objective is the detection and prevention of diversion of significant quantities of nuclear materials from peaceful nuclear activities.
To obtain this objective

- material accountancy
- containment design
- surveillance
- physical protection

will all be applied.

5.1 Material accountancy

Accountancy means the determination of the quantity of fissile materials within the plant and its change over a period of time.
It is accomplished by:

- definition of the material balance areas
- selection and definition of the key measuring points for determining the nuclear material flow
- selection and definition of the key measuring points for determining the physical inventory
- selection of analytical and measuring methods for fissile material which are the basis for accounting and operating records, accounting reports and special reports

- frequency and procedure for evaluating the physical inventory.

5.2 Containment design

The construction of the conversion unit must be designed in such a way that substantial protection against unauthorized access to fissile material is provided. It will be part of the design to provide that these protective systems are integrated to ensure the highest degree of resistance against diversionary activities.

5.3 Surveillance

The plant is designed in such a way as to facilitate an efficient surveillance by the inspectors of international authorities who are entitled to exercise controls in the plant within the context of the procedures described above.
National authorities and the plant management will support the international inspectors.

6. Ventilation

The ventilation of the conversion plant is integrated into the ventilation system of the MOFFP (already described in the MOFFP base case).

7. Safety Analysis

The integrated MOFFP concept, the aspect of technical safety as well as the impact on the environment are part of the safety analysis for the whole plant.

For internal impact, like fire, spread of contamination, etc. preventive measures are provided, such as the use of inflammable or flame resistant materials or the enclosure of the nuclear materials in a containment consisting at least of two solid barriers with zones of decreasing air pressure from the outer to the inner barrier.

Fire detectors, extinguishers, contamination and criticality detectors are installed.

8. Plant Diagram

The plant diagram is already described in Task 2 (Basc Case Integrated Short Term Pu Nitrate Storage) page 8 and 9).

9. Cost Estimates

The conversion plant is part of the Mixed Oxide Fuel Fabrication Plant, therefore the cost estimate for the conversion plant cannot be given separately. Some cost data may be taken from the relevant chapter of the RFCC-Study [1] of the IAEA.

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[1] see Regional Nuclear Fuel Cycles Centers, Vol I, 1977, report of the IAEA study project, IAEA Vienna